GEOGRAPHIC INFORMATION SYSTEMS (GIS) DIFFUSION IN HIGH SCHOOLS

by

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A thesis

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ABSTRACT

Geographical information systems (GIS), the phenomenon for this study, was introduced as a section in the Revised National Curriculum Statement (RNCS) for school Geography in 2006 in South Africa. It also appears in the latest Curriculum addition, namely the Curriculum and Assessment Policy Statement (CAPS), for Geography. It is taught in the further education and training (FET) phase of high school (Grades 10, 11 and 12) as a critical part of map work, which is assessed in Paper 2 of the geography examinations for these grades. An acknowledgement of the high failure rate of matric learners (grade 12) in the high stakes examination in Geography is testimony to the challenges that teachers and learners face. However, few studies have explored GIS diffusion locally, through the lens of teachers: their beliefs and views, the way it is taught and why, given that it is a practical component of the curriculum dependent on school resources, such as access to electricity, computers, GIS software and teachers' innovativeness. Hence, there was a need to understand how GIS is taught and to identify the challenges which teachers face when they teach this section of the curriculum. The aim of the study was thus to explore GIS diffusion through the teaching of GIS in high schools in the Frances Baard district of the Northern Cape province of South Africa, a context where there is a dearth of research on GIS teaching in Geography. Key objectives of this study included an exploration of the pedagogical approaches used by geography teachers when they teach GIS and the reasons why they choose these approaches. The study also sought to examine teachers' attitudes towards the inclusion of GIS in Geography in the FET phase and their views about teaching it. The study fell within the pragmatist paradigm, and a sequential explanatory mixed methods and multiple-case study design research design was adopted. Questionnaires, interviews, and classroom observations were used to generate data. Purposive convenience sampling was utilised to select the most accessible participants. In total, 60 geography teachers participated in this research. The study used Rogers' (2003) diffusion of innovation theory and the technology acceptance model (TAM) as frameworks. The data from the interviews and classroom observations were analysed thematically using framework analysis, whilst the data from the questionnaires were analysed quantitively using SPSS, and the application of the Fisher's test and ANOVA. The study integrated the findings and drew inferences using both qualitative and quantitative data.

Teachers were found to have positive attitudes about the inclusion of GIS in the curriculum and they displayed an appreciation of its importance in society. However, the study found that the use of GIS in the classroom is constrained by several technical and non-technical challenges. It was revealed that seasoned teachers (who have been in the teaching profession for a long time) do not easily accept curriculum changes and need in-service training to enhance their knowledge and confidence in new content, such as GIS when it's introduced into the curriculum. Further, the research noted that the majority of teachers used teacher-centred pedagogical approaches when teaching GIS, utilising mainly the textbook. It was a significant finding that the teachers lacked GIS training, and that they had inadequate GIS content knowledge. Furthermore, teachers' integration of GIS in their geography lessons, was impaired by infrastructure challenges in the school with electricity and internet connectivity. The study makes theoretical contributions to the diffusion of innovation, as well as technology acceptance models from a GIS lens, in addition to Geography teaching in South Africa.

Many teachers resorted to thus 'teaching about GIS' rather than 'teaching through GIS'. As a result, 'perfunctory GIS teaching' was evident in the mechanical, minimal effort, unenthusiastic manner of teaching. Many teachers were 'curriculum cramming' - they hurtled through the GIS section of the CAPS and failed to integrate it with other Geography topics in the curriculum due to the curriculum and assessment demands for GIS. Whilst there is value in teacher-centred pedagogical approaches to teaching some aspects of GIS, the current curriculum is constructivist and teachers' weak GIS content knowledge base contributed to influencing the pedagogical approaches which they opted to use when teaching GIS. The study advances an ecosystems model to understand and respond to the GIS teaching challenges facing Geography teachers in the Frances Baard district of the Northern Cape.

Thus, the study recommends that it is critical for teachers to receive GIS support such as GIS training on compliance to CAPS and to build sufficient content and pedagogical content knowledge to be confident in teaching this section. The research also recommends that, in order to bridge the gap in GIS knowledge, a seeding model of GIS can be pursued in the province. Alternatively, the GIS lessons can be skype/zoom taught if there is a lack of access to electricity so that schools can learn simultaneously. These models can help reduce the failure rate in the GIS section of the matric exit examination and it can assist to promote the subject of geography, especially for those learners who are intent on pursuing GIS linked careers.

Other insights gained from the data suggest that the pedagogical approaches used, the knowledge of GIS by teachers, and their attitudes towards GIS can be improved if other stakeholders (apart from the Department of Education and their district offices), such as the Environmental Systems Research Institute South Africa, universities and local municipalities that have access to GIS expertise and resources help to set up collaborative project endeavours to provide GIS expertise, to workshop teachers and to tutor learners in the GIS seeding of schools.

DECLARATION

I, Johane Hlatywayo, student number 206523448, declare that this thesis contains my own work. All sources that were used have been referenced accordingly. This research has not been previously accepted for any degree to any university and is not being currently considered for any other degree at any other university.

Signature ______[redacted]____________________

Johane Hlatywayo

Date _______07 December 2021________________________

As the candidate's supervisor, I agree/do not agree to the submission of this thesis.

Signature ___________[redacted]_______________

Date ___23 December 2021_____________________________

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GLOSSARY OF TERMS

Learners/students

In this study, the terms will be used interchangeably and will have the same meaning. A learner is a person who is in the process of acquiring practical skills, who is taught by a teacher. A learner is a person who is engaged in studying academic subjects and acquiring knowledge.

Educator/teacher

In the South African context, the word educator is the official, designated word for what is universally known as teacher. The two words will both be used interchangeably and will mean the same.

FET learner

In the South African education system, any learner in the further education and training (FET) band – that is, Grades 10, 11 and 12, or who is attending an FET college – is called an FET learner. In this research, the FET learner refers to learners in Grades 10, 11 or 12 in high school.

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

CAPS	Curriculum Assessment Policy Statement
DOI	Diffusion of innovation
ESRI	Environmental Systems Research Institute
FET	Further education and training
GIS	Geographic information systems
NCS	National Curriculum Statement
ICT	Information communication technology
PCK	pedagogical content knowledge
PGCE	Postgraduate Certificate in Education
SADTU	South African Democratic Teachers' Union
TAM	Technology acceptance model
RNCS	Revised National Curriculum Statement

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Teachers play a critical role in the learning of new technology in classrooms throughout the world's education system (Höhnle, Fögele, Mehren & Schubert, 2016; Maude, 2018; Collins & Mitchell, 2019). One such new technology is Geographic Information Systems (GIS). It is used and taught in a variety of countries, both developed and developing. GIS is taught in both higher education and secondary schools. It is primarily taught as part of geography degrees in higher education, and it is taught as part of the geography curriculum in high schools (my research focus). In other subjects, such as mathematics, history, and social sciences, it can be used as a technological tool to aid understanding of concepts taught. As such, this chapter provides a brief overview of geographic information systems (GIS), the phenomenon under consideration in this study. I also discuss the study's rationale and significance, as well as the research problem and objectives.

The abbreviation GIS also refers to Geographic information Science (GIS), which is the academic discipline that studies geographic systems (Madurika & Hemakumara, 2017). GIS stands for Geographic Information Systems, which is a system for storing, updating, analysing, displaying, and manipulating geographical data information about locations on the world (Bevainis, 2008). This approach uses the computing power of computers to answer geographic problems by organising and showing all types of data about locations in a number of formats, including maps, charts, and tables. GIS is thus defined as a system that “collects, displays, manages and analyses geographic information” (ESRI, 2013, p. 23). It can capture and present data, manage data (including storage and maintenance), manipulate data and analyse data, and present data (Huisman & Rolf de By, 2009). As such, GIS is an exciting development for geography education, locally and internationally, that introduces various new technologies into the classroom and for field work. GIS as a technology focuses on problem solving (Mzuza & van der Westhuizen, 2019), whereas GIScience or computational science aims to provide learners with spatial critical thinking skills (Silviariza, Sumarmi & Handoyo, 2021). Currently, GIS is being taught in high schools in many developed countries’ such as the USA, Canada, Finland, Japan and Australia. Though lagging behind, Southern African countries such as South Africa, Botswana, Malawi, Zambia, Namibia, and Zimbabwe are incorporating GIS into their university and high school curricula (Sack, 2018; Collins & Mitchell, 2019). According to research, learning using GIS (Mzuza & van der Westhuizen, 2019) and using GIS as a tool (as recommended in the current South African school curriculum) aids pupils in developing spatial thinking, planning, and environmental awareness abilities (Jakab, Ševčík, & Grežo, 2017; Hong, 2017; Hong & Melville, 2018; Mzuza & van der Westhuizen, 2019).

There is thus a growing interest in GIS education internationally (Baker, Palmer, & Kerski, 2009). The global growth of interest in GIS is evident in its emergence as "one of the 25 most significant developments that transformed the life of all humanity in the 20th century" (Demirci & Karaburun, 2009, p. 169), and it's listing as one of the three most important and emerging scientific fields. Several countries, including the United States of America, Japan, Finland, India, Canada, Rwanda, Ghana, and South Africa, have implemented GIS in high schools and have invested heavily in programs that use GIS in education (Pelgrum, 2001). Proper implementation of GIS technology in high schools can bring imperative instructional change that is information communication technology (ICT) based and, specifically, GIS-based teaching in geography. It is argued that this change will help transform learners into active knowledge constructors (Govender, 2008). According to Demetriadis et al. (2007, p. 19), "an educated citizen in the year 2020 will be more valuable as an employee, because he or she will be able to produce more builders of theory, synthesizers, and creators of strategy than one who manages facts." This statement has value because a learner who understands GIS will have a better understanding of how the world works on a global scale and will be better able to solve spatial problems through manipulation and the use of cutting-edge technology.

The global growth in GIS technology use has affected various aspects of life and institutions, including schools. Failure to adopt this new technology may be disastrous for the teaching of certain subjects at schools given that the South African education system is experiencing a paradigm shift, by incorporating technology into lessons. One example is the change from traditional methods of teaching, to more technological applications (Weber, 2008) and another is in the introduction of new subjects, for example Robotics will soon be a school subject. South Africa is in the process of "developing a coding and robotics curriculum to be included from grades R-9" (BUSINESSTECH, 2021 p.1). As a result, the incorporation of GIS into the geography curriculum in the further education training phase (FET) of high school is seen as a vital step towards increasing the content and quality of teaching and learning in the topics of geography, as well as the teaching methods through technology (Scheepers, 2009).

1.2 CURRICULUM CHANGES IN SOUTH AFRICA

Since 1994, South Africa has implemented a number of curriculum reforms, including Curriculum 2005 (C2005), the National Curriculum Statement (NCS), and, most recently, the Curriculum and

Assessment Policy Statements (CAPS). All these reforms involved changes to the curriculum's topics or sections, as well as the pedagogical approaches that teachers must employ to maximize learning. Consequently, these curriculum changes have afforded teachers the opportunity to gain new content knowledge and change the ways (teaching methods) in which they teach topics in geography, in order to comply with the Department of Education’s policy changes which is underpinned by a constructivist epistemology and learner centred teaching approaches.

Schools, colleges and universities alike are embracing the use of ICTs in an integrative way, where teachers are encouraged to infuse technology, such as GIS, in the subject of geography. In South Africa, GIS was added as a section to the Revised National Curriculum Statement (RNCS) in geography in 2006 (Breetzke, 2007; Innes, 2012). It is also included in the new geography curriculum-CAPS (DoE, 2010). GIS is taught in Grades 10, 11, and 12 during the FET phase. It is part of map work, which is tested in Paper 2 of the examinations in these grades. Few studies have explored the way it is taught, especially its practical applications, which is dependent on school resources, such as access to electricity, computers, GIS software and teachers’ innovativeness. The few studies that have been done (Du Plessis & Van Niekerk, 2012; Fleming, 2015) were undertaken years ago and they indicated that only the theoretical aspects of GIS were being taught. A few schools, which can afford the huge cost of buying computers and GIS software were integrating GIS theory with practical work, that is, GIS application (Fleming, 2015).

Since GIS was introduced in the geography curriculum, more than a decade ago, there is a need to explore how it is currently taught, and to identify the challenges that teachers experience. Furthermore, an acknowledgement of the ongoing high failure rate of matric learners (in the school exit examination) in geography Paper 2 – in the GIS section – is testimony to the challenges that teachers and learners are experiencing. This study, therefore, sought to explore the pedagogical approaches used by geography teachers when they teach GIS in high schools in the Northern Cape, an unresearched GIS schooling context and one which is understood to be a largely rural, poor province. The study also sought to examine geography teachers’ attitudes and views and to determine the reasons for GIS being taught in particular ways in high schools.

1.3 ADVANTAGES OF GIS

As evidenced by the literature, introducing GIS into classrooms has a number of benefits. GIS encourages learners to acquire higher-order thinking skills such as critical thinking and problem solving (Fitzpatrick & Maguire, 2001; West, 2003; Bednarz & van der Schee, 2007). GIS education also enhances spatial thinking abilities in learners (Hall-Wallace & McAuliffe, 2002; Lee, 2005;

Lee & Bednarz, 2009; Demirci, 2011). Additionally, GIS is shown to assist learners to cultivate a positive attitude and values about geographical topics (West, 2003; Aladağ, 2010). Thus, it is evident that several scholars believe that GIS has significant advantages for learners.

1.4 RATIONALE OF THE STUDY

There were numerous reasons for embarking on this study. The following section is going to highlight some of the rationale which informed me to carry out this research.

1.4.1 PERSONAL RATIONALE

My experiences as a high school geography teacher in Zimbabwe and South Africa influenced me to commence this study. I encountered challenges teaching GIS, due to my own lack of knowledge, and my negative attitude towards GIS. I did not have time to learn this technology, due to time constraints and a lack of physical resources such as computers and the relevant software. Consequently, most of my learners performed poorly in the examinations. In addition, most of the geography teachers whom I had discussions with, stated that they used an exam-based theory approach, and taught learners to cram and memorise answers for the GIS section of the geography Paper 2 examination at matric level in South Africa. They were, thus, teaching GIS for the high stake's assessment, and not for understanding of the technology and its application in the world.

Prior to the addition of GIS in the geography curriculum in 2006, teachers had received no GIS training. My personal experience, as a teacher of geography detailed above, confirms this claim. As a practicing geography teacher, I was not afforded the opportunity to go to the GIS workshops that were taking place in the province of KwaZulu-Natal, where I worked at the time. Only the subject advisor attended the workshops on GIS, and it was hoped that subject advisers who attended these workshops would transfer what they had learnt to the teachers in the province. This indicates that the implementation strategy for transferring this technological innovation (GIS) was flawed, as it omitted the direct training of geography teachers.

My experience in Zimbabwe was similar to what I experienced in South Africa. GIS aspects are not taught as part of the geography syllabus. Furthermore, the geography syllabus merely makesreference to GIS, and it is not mandatory for geography teachers to teach the topic. There is no training on how GIS should be taught in Zimbabwean schools.

My experiences and observations triggered my curiosity to find out how GIS is being taught in a broader geographic context and what pedagogical approaches were being used to teach GIS currently. It is hoped that the findings of this study will add to the body of knowledge on how to improve GIS teaching in South African schools.

1.4.2 PROFESSIONAL RATIONALE

My professional justification for the study is founded on an acknowledgment of the ongoing high failure rate of matric learners in the GIS section of the geography Paper 2 examination. The possibility that geography teachers are poorly trained for this section of the syllabus compelled me to undertake this research and to determine geography teachers' professional competences. My observation and assessment at Sol Plaatje University, where I am a lecturer in Geography, established that students enrolled for the B.Ed. degree find the GIS module, which is offered, very difficult to understand, and they often perform poorly in this module.

Sol Plaatje University, a tertiary institution in the Northern Cape province, opened its doors for the first intake of students in 2014, and it offers geography as a subject with a GIS component. The university started with three schools, namely, the Schools of Education, Natural Applied Sciences, and Retail Management Sciences. Students who enrol for Education Studies major in geography, mathematics, technology or biological sciences. The students who major in geography and teach the subject at the FET phase are of interest to this study, as they studied GIS. The students are taught both the theory and practical aspects of GIS in the computer laboratory. The module evaluation that is done at the end of each semester by the pre-service teachers indicates that there are considerable differences between the way they were taught GIS in high schools, and their university experiences of GIS. The pre-service teachers in geography stated that they were only taught the theory part of GIS at high school, and when teaching unfolded at school, they read from textbooks and they were provided with notes without explanations, which made the section on GIS the most difficult part of the subject to understand. The combination of theory and practicals in the module at Sol Plaatje made the students enjoy geography and their attitudes and views towards GIS improved, because of the way in which it is taught at the university. Thus, I was able to see first-hand that exposure to GIS promotes its enjoyment which could positively influence its future use in the classroom.

1.4.3 CONTEXTUAL RATIONALE

The contextual rationale for the study is related to GIS and location: namely in high schools in the Northern Cape province. Though studies on GIS teaching in high schools have been carried out in European countries and in some African countries, those carried out in South Africa have not focused on the Northern Cape province. No studies on GIS teaching in high schools have been carried out in this province, though a number of GIS-related research studies have been done in provinces such as the Western Cape, Gauteng and KwaZulu-Natal. Hence, my motivation to carry out this research in this province is based on the dearth of research on GIS in the Northern Cape. It should be noted that, in general, few studies have been conducted since the inclusion of GIS in the geography high school curriculum in 2006.These include studies by Breetzke (2007); Scheepers (2009); Innes (2012); Fleming (2015); Mzuza and van der Westhuizen (2019); Mkhongi and Musakwa (2020) and Zondi and Tarisayi (2020) which were carried out in South Africa.

It is against this background that this research was conceived. The research sought to explore how GIS is being taught and why- if there are barriers that slow its diffusion in secondary school geography, with some recommendations on what needs to be done to advance its teaching.

1.5 POTENTIAL SIGNIFICANCE OF THE STUDY

The significance of this research is that it will contribute to knowledge on the pedagogical approaches used to teach GIS in high schools in South Africa. The contribution will aim to promote the innovation and use of GIS in the advancement of geography education. It is hoped that the findings of the study will:

- Provide theoretical knowledge and views on teachers' perceptions of GIS and its diffusion in high schools.
- Determine the factors that can contribute to increased use and integration of GIS in high school geography studies; and
- Promote an understanding of the attitudes and views of geography teachers regarding their teaching of GIS in high school Geography.

Hence, this study should be of value to institutions of higher learning that train teachers, as well as schools and government departments that are interested in GIS development and in promoting critical thinking by learners in South Africa.

The literature reviewed shows that there is a considerable gap on content mastering in GIS and its application by schoolteachers (Kerski, 2003; Jones, 2007; Keiper, 2007; Kerski, 2007; West, 2007; Innes, 2012). The findings of this study add insights on GIS data in the Northern Cape province, as well as the Northern Cape Provincial Department of Education's implementation of GIS in schools. The introduction of the new Sol Plaatje University and its initial programmes, such as the B.Ed. in geography, makes it prudent for the university to embrace this opportunity and become the hub that can assist to coordinate the rollout of GIS in education in the rural province. This research study also assists to gather relevant information on geography teachers and in particular, GIS which has a role in the fourth industrial revolution, all of which will enable the university to address the precise needs of 21st century geography educators.

1.6 RESEARCH PROBLEM

In 2006, the NCS introduced GIS in geography at the school level for the first time. The GIS curriculum was gradually and methodically integrated into the RNCS for geography over three years, beginning with Grade 10 in 2006, Grade 11 in 2007, and Grade 12 in 2008. GIS also appears in the CAPS for geography (DoE, 2010), which is a curriculum addendum to the NCS.

The GIS section covers the following topics:

Grade 10

- Concept of GIS
- Reasons for the development of GIS
- Concept of remote sensing
- How remote sensing works
- GIS concepts: spatial objects, lines, points, nodes and scales

Grade 11

- Geographically referenced data
- Spatial and spectral resolution
- Various data types: line, point, area, and attribute
- Raster and vector data
- GIS application to all relevant grade topics
- Tracing different types of data from existing maps, photographs, fieldwork, or other records

Grade 12

- GIS concepts: remote sensing, resolution
- Spatial and attribute data; and vector and raster data
- Data standardisation, data sharing and data security
- Data manipulation includes the following operations: data integration, buffering, querying, and statistical analysis.
- Government and private sector use of GIS
- Relevance to all Grade 12 topics Create a "paper GIS" on layers of tracing paper using existing maps, photographs, or other records.

The CAPS document does not dicate how teachers should teach these topics. However, the CAPS document supports and promotes the teaching of these GIS topics using constructivist approaches. Constructivism is the model which emphasizes the fact that learners construct or build their own understanding. Since the introduction of GIS in the geography curriculum, teachers and learners have struggled to understand this section of geography. The literature shows that Geography teachers do not have adequate knowledge or physical learning materials for GIS, and learners are not doing well in this section. The Department of Basic Education in the Northern Cape province reports that, in exams, the majority of the Grade 12 learners in geography leave the GIS section unanswered (DoE, 2014). One of CAPS's objectives is to encourage the use of new technologies in geography, such as ICT and GIS. In South Africa, it is argued that learners should be technologically competent (Amory, 2014) thus, making it mandatory that educators use technology in their instruction. Thus, this study sought to explore GIS diffusion through unpacking teachers' views, attitudes, teaching and the challenges in GIS teaching.

1.7 AIM AND OBJECTIVES OF THE STUDY

The study's goal was to explore GIS diffusion by honing in on how it is taught in high school geography classes in South Africa's Northern Cape area: Frances Baard district. The objectives of this research were:

- To examine teachers' attitudes towards the teaching of GIS in geography at the FET phase;
- To examine teachers' views about GIS teaching in geography in the FET phase;
- To explore the pedagogical approaches used to teach GIS; and

- To examine the reasons why geography teachers, use these particular pedagogical approaches to teach GIS.

The aim and objectives are discussed later in detail.

1.8 RESEARCH QUESTIONS

The research asked the subsequent questions, which will be discussed in greater detail later:

- What are teachers' attitudes towards GIS in geography in the FET curriculum?
- What are the teachers' views about GIS in geography in the FET curriculum?
- What are the pedagogical approaches used to teach GIS?
- Why do teachers use these pedagogical approaches to teach GIS?

1.9 DELIMITATIONS

The research was conducted at particular high schools in the Northern Cape province of South Africa, and it involved only those educators who teach geography from Grades 10-12 at the FET level.

1.10 RESEARCH DESIGN AND METHODOLOGY

The study uses a pragmatist paradigm to solve the above-mentioned research topics. The pragmatic paradigm is a worldview that prioritizes "what works" over what is objectively and absolutely "true" or "real." (Creswell & Plano Clark, 2011, p.13) and (Creswell, 2013). It is founded on the premise that researchers should take the philosophical and/or methodological approach that is most appropriate for the particular research challenge at hand (Teddlie & Tashakkori, 2009). I used a mixed methods approach which leans more towards the qualitative than the quantitative. Mixed methods research combines qualitative and quantitative research methods. This is usually done so that the two methods can complement each other and increase the knowledge of what is being researched in a more meaningful manner than either model could achieve alone (Creswell & Plano Clark, 2011). I used questionnaires, interviews, and classroom observations to gather the data from participants. A sequential explanatory mixed research design was used. The aims of pragmatism are to give insight and meaning on the observable practices of the participants during the research (Kivunja & Kuvini, 2017). In this research, I wanted to understand GIS diffusion thorugh exploring the pedagogical approaches used by geography teachers when they teach GIS, teachers' views, attitudes etc. The first phase of the study was carried out via a questionnaire distributed to 50 geography teachers, which included both open and closed ended questions. The second phase of the study involved interviewing 10 geography teachers (before and after observing their lessons) and observing them whilst they taught GIS lessons.

1.11 DEFINITION AND EXPLANATION OF KEY CONCEPTS

This section will define and discuss some of the key concepts that underpin this study.

Geographic information systems

GIS is defined as an "integrated software system for the handling of geospatial information: for its acquisition, editing, storage, transformation, analysis, visualisation, and indeed, virtually any task that one might want to perform with this specific information type" (National Research Council, 2006, p. 159).

Information communication technology (ICT)

Information communication technology referrers to all "technologies that give access to information through telecommunication" (Ratheeswari, 2018, p.2). It is associated with information technology (IT) but focuses on communication technologies. It includes the internet, wireless networks, cell phones, and other forms of communication.

Teaching about GIS

Teaching about GIS means that the "technology is marginal to the intellectual mainstay of geography and, therefore, the area is taught as a technological field with an assortment of marketable skills" (Kerski, 2009, p.15).

Teaching through GIS

Teaching through GIS refers to the "use of GIS to teach geographic concepts" (Kerski, 2009, p.16). In this case, GIS is viewed as a means to discover the spatial patterns of geographic phenomena rather than an end in itself

Innovation

Innovation refers to an "idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers, 1995, p. 11).

Digital divide

The digital divide is defined as the technological gap between those who have access to technology and those who do not (Goldstern, 2010, p. 33), or as the "consistent divide between educational institutions that are well equipped with computer hardware and software and those that are not" (Kerski, 2008, p. 339 quoting Warschauer, et al., 2004).

Diffusion

Diffusion is defined as the "process by which an innovation is communicated among members of a social system over time through specific channels" (Rogers, 1995, p. 10).

Attitudes

According to the Oxford Dictionary, attitude is a fixed way of thinking, or feeling about something, in this case—thinking and feeling about GIS. People's attitudes toward new technology (such as GIS), according to Rogers (1995), are a critical component of its diffusion.

Pedagogy

Pedagogy, in its broadest sense, is the art (and science) of teaching (Bhowmik, Schäfer, & Metz, 2013). Most teachers use a range of teaching tactics since there is no single or universal approach that works for all pupils. With distinct groups of learners and in various circumstances, different tactics are applied in varying combinations. Bhowmik, Schäfer, and Metz (2013) found that some tactics are more suited to teaching specific skills and information than others. The term pedagogical approach/es (which I prefer) refers to the “interactions between teachers, learners, and the learning environment and the learning tasks” (Murphy, 2008, p. 35). This broad, all-encompassing term in this study embraces the way teachers and learners interact with one another, the content (theory and practice of GIS), its practical application requirements, including resources, and the instructional approaches used in the classroom. Pedagogical approaches are typically divided into two categories: teacher-centred and learner-centred. Despite the fact that these two techniques appear to be diametrically opposed, they usually complement each other in the pursuit of educational objectives. For example, a teacher-centred method might be good for presenting a new theme, but a learner-centred approach might be required to allow learners to explore these ideas and acquire a deeper understanding.

Teaching approach

The way a teacher considers content when deciding how to teach it is referred to as the teaching approach. There are different types of teaching approaches in education. The 21st century demands teaching approaches that cater for specific aspects of learner learning. Present-day demands for skills and technology have resulted in four commonly used teaching approaches:

- Teacher-centred,
- Learner or learner-centred, and
- Collaborative learning.

This research considers pedagogical approaches to be inclusive of teaching approaches as well. In Chapter 2, I will explain these pedagogical approaches in greater detail. In this research, pedagogical approaches include the teaching approaches in teaching GIS in geography. This was adopted as a result of the overlap between the concepts of ‘pedagogical approaches’ and ‘teaching approaches/strategies’ (Murphy, 2008). Furthermore, this overlap in meaning of these two concepts was also noted during data generation. When geography teachers were requested to state the pedagogical approaches, they use to teach GIS, they stated the teaching approaches / strategies / methodologies they used, instead. This explanation is important, because it will eliminate any confusion that might arise from the usage of terms.

Learning

The term "learning" has several meanings. In general, it refers to a step-by-step process through which an individual acquires permanent and long-lasting changes in knowledge, behaviours, or ways of processing and understanding the world (Prozesky, 2000). People do not just learn knowledge and facts, but they also learn skills and attitudes and these knowledge and skills can be learnt formal and informal. People can go into schools or institutes of higher learning and acquire the knowledge in the classroom or acquire it informally through what they experience on daily basis. For instance, teachers can tap into the knowledge learners have already and build on such knowledge. Learning becomes more applicable in this case when it is related to the needs of individuals (Prozesky, 2000). Learning is related to this research because one of the goals was to investigate the pedagogical approaches used by geography teachers to enable learners to acquire GIS skills and knowledge.

Outline of Chapters

The thesis is divided into six chapters.

CHAPTER 1 describes the study's background, rationale, and significance. The chapter also explains what GIS is for the purposes of this study, and some of the benefits it can bring to learners within the schooling context in South Africa and other countries.

CHAPTER 2 reviews the literature on the history of GIS, pedagogical approaches used in teaching geography, and conceptual frameworks on which this study was based. The information provided in this chapter underscores the way ICT innovation is changing, the way subjects are currently being taught, and why it is advantageous for educators to be equipped technologically in a rapidly changing world. Discussions on various models used in technology diffusion, adoption and use in various sectors are reviewed in this chapter.

CHAPTER 3 describes the methodology and design of the study, which was used to collect rich data from the participants, who were educators. This chapter also elucidates why the pragmatist paradigm and mixed methods approach were chosen for the study. The instruments used, the types of data generated, and the analysis methods for this study are also discussed.

CHAPTER 4 focuses on the results of the quantitative and qualitative data generated on the pedagogical approaches used by geography teachers, their attitudes and the views of the teachers. It also includes the reasons why and how teachers teach GIS in in the Northern Cape province’s sample schools.

CHAPTER 5 discusses the findings on the pedagogical approaches which the participant teachers used when they were teaching the GIS section. The discussion links the study’s findings with the literature reviewed in Chapter 2.

CHAPTER 6 delves into the study's key findings. The insights are divided into three categories: theoretical, conceptual, and methodological. These findings also aid in a better understanding of pedagogical approaches to teaching GIS, as well as making recommendations for GIS instruction in the province's high schools.

1.12 CONCLUSION

This chapter introduced the study (and its key concepts), as well as outlined the study's background and rationale in the context of South Africa's introduction of GIS into the geography curriculum for Grades 10-12. (FET phase of schooling).

The next chapter discusses the relevant literature, theories and concepts that assisted to provide a framework for this study on GIS usage and its diffusion. Relevant theories for the current study are discussed. The pedagogical approaches used to teach GIS in other countries are also explored to create a background for this study.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

In the previous chapter, I introduced the study, by explaining the rationale, research design including methodology, objectives and critical questions of the study. This chapter provides a review of the literature pertinent to this study. It is asserted that researchers have two main aims when they conduct a literature review (Snyder, 2019). First, it helps to map and assess the research area so as to motivate for the aim of the study by providing information within the framework of the research to see whether the research being undertaken fits in with the “broader picture” of what is already known about the research topic from earlier research. The review is of paramount importance, because it identifies what other researchers have done in the study area, and it identifies the knowledge gaps. Secondly, a literature review is used as an end in itself, whereby the literature is used to update practice and to provide an appreciation of what exists in the world in relation to the research topic. This study aimed to explore GIS diffusion, hence how it is taught in schools, as well as the pedagogical approaches used by teachers, as well as the views and attitudes of teachers toward GIS education were valuable.

I, therefore, start this chapter by discussing the emergence, growth and key aspects of GIS on a global scale, then continentally (in Africa) and then nationally (in South Africa). The challenges and obstacles faced by countries that try to include GIS in geography in their curricula for high schools will also be considered. Furthermore, in this chapter, the pedagogical approaches used for teaching geography with a focus on GIS will be discussed. Literature related to teachers’ attitudes and views on GIS inclusion in the geography curriculum in South African secondary schools will also be reviewed. Exploring this was important, because I wanted to determine if teachers’ attitudes and views had any influence on the way GIS is taught in the current study. Thereafter, the chapter explains the conceptual framework for this research. Rogers’ (2003) diffusion of innovation (DOI) theory and Legris’ (2003) technology acceptance model (TAM) were used for the theoretical framing. This is followed by a discussion of the reasons for South Africa’s introduction of GIS in high schools, and some ideas from the literature which provides some insights into why it is taught the way it is, currently in this specific case.

2.2 THE ROLE OF ICT IN EDUCATION

ICT plays a critical role in almost every aspect of government, business, and individual operational processes. Computer networks, for example, are widely used as an e-government medium to improve both government-to-public communication and state service delivery (Ncube, 2018; Department of Education, 2003; Clayton & Ash, 2004). There is also a widespread belief among urban and rural residents that using ICT can effectively contribute to improving educational quality (Mlitwa, 2006).

GIS, which falls within the ambit of ICT, can be used as a tool to teach geography. Using computers in learning improves the quality of learning and introduces learners to technology-enhanced practices after they finish school, allowing them to function more efficiently in today's technology-based economy (Department of Education (DoE), 2003; Ncube, 2018). During the course of learning through computers, learners can access materials, such as course exercises and past examination papers, and they can exchange ideas in real time, regardless of the diverse locations of learners. Educators from all over the world can also share ideas and discuss issues affecting the teaching profession (Mensah, 2004 cited in Tire & Mlitwa, 2007). Finally, most schools, especially urban schools, teach computer application technology (CAT), and some do offer information technology (IT). In contrast, few rural schools have access to ICT (Mdlongwa, 2012; Dzansi & Amedzo, 2014; Mwapwele, et al., 2019). The situation in most rural schools can be worsened by a lack of connectivity to both electricity and therefore the internet.

Research has shown that the use of GIS in education can have major benefits for both teaching and learning, and it can enhance administrative processes. However, since the inception of GIS in the South African geography curriculum in 2006, little or no progress has been made to transform GIS from being taught theoretically to being taught practically in a GIS laboratory or classroom (Breetzke, Eksteen & Pretorius, 2011). South Africa’s education policy does not demand that GIS be taught and tested practically. Of course, this policy failure does not account for geography teachers’ limited efforts to integrate theory and practical approaches in the teaching of GIS. Tire and Mlitwa (2007, p.152) observe that "schools with computers do not use the devices adequately, due to a lack of relevant programs, problematic learner/computer ratios, and, most troublingly, a lack of computer skills among educators." Despite the advantages that GIS may bring for learning geography, most schools in rural and township areas of South Africa either lack access to computers and the internet or lack the necessary skills and programs to explain the advantages of ICT and GIS (Tire & Mlitwa, 2007; Breetzke, Eksteen & Pretorius, 2011). Finally, Tire and Mlitwa’s research, carried out in the Northern Cape province, indicated that the use of

ICT in rural areas is inadequate. Thus, providing schools with computers is not a panacea for innovation diffusion problems in schools; instead, the solution may lie in the beneficial use of these technologies by all schools as is argued by Mlitwa (2006). It is argued that even if the resources are made available in most rural schools, ICT is still not frequently and effectively used in teaching (Mdlongwa, 2012; Dzansi & Amedzo, 2014; Mwapwele, et al., 2019).

It is necessary to trace the history of Geography and GIS introduction in South Africa in order to better understand the nuances of GIS locally within the subject of geography.

2.3 HISTORY OF GEOGRAPHY IN SOUTH AFRICA

The following section outlines a brief history of geography education and the introduction of GIS in South African high schools. I cannot avoid discussing the history of South African education without referring to the impact of apartheid and racial segregation-its grouping of people according to skin colour (Lim, 2007; Innes, 2012) as this has relevance for resourcing in schools as GIS teaching is related to school resources. From the colonial period through the founding of the Republic of South Africa, geography was taught at the matriculation level (commonly known as matric) in all four provinces. However, the subject's introduction to other race groups was hampered by insufficient funding (Manik, 2016), a chronic scarcity of specialist teachers, and language-related issues. Geography content taught at previous 'whites only' schools had more depth (and was thus of better quality) than the geography being offered in township schools, attended by black learners. Schools for different racial groups were resourced differently, advantaging some (white learners) and this affected the performance of the majority of learners.

Geography was initially taught in fragmented ways by mission schools, and at the primary level, it was frequently combined with history and nature study to form environmental studies (Innes, 2012). At present, geography is taught as a stand-alone subject in Grade 10 (Binns, 1999). Like any other country, the basic education curriculum of South Africa has gone through various changes, in this case, mainly since 1994 when SA became a democracy and there was a need to overhaul the school curriculum. This was because the curriculum was colonised, that is, it was influenced by colonial ideas and thinking which demeaned non-whites and which lacked critical thinking thus providing the masses of non-whites with a sub-standard inferior education (Manik, 2016).

2.3.1 FORMULATION OF THE CURRICULUM

A step back prior to 1994, reveals that the formulation of the geography curriculum followed a top-down approach (Binns, 1999). Past syllabi were dictated from the national level and less consultations were done with teachers who teach the subject in the schools (Innes, 2012). Van Harmelen (cited in Binns, 1999) claimed that syllabi lacked social critical thinking. The syllabi did not encourage teachers to be innovative in their teaching approaches. The syllabi also lacked a focus on skills acquisition in map interpretation. For instance, the first objective of the 1985 geography syllabus was the acquisition of what was perceived to be an essential body of knowledge, which indicates the inflexibility and lack of ingenuity that dominated planning in the past (Binns, 1999). It is reported that the curriculum was the result of Eurocentric thinking about academic geography, and it reflected the traditional values of white South Africa (Breetzke, Eksteen & Pretorius, 2011). During that period, few learners enrolled for geography at schools. Few learners chose geography at universities and colleges due to various reasons, such as that it was factually difficult, it had unattractive textbooks, and that the courses suffered from content overload, and they yielded relatively poor results (Dube, 2012; Fleish et al., 2019). Furthermore, the perception was that geography did not prepare learners for employment (Breetzke, Eksteen & Pretorius, 2011). In addition, teachers complained that geography was so overloaded, that it was difficult to cover the syllabus during the school time that was available. The nature of the school examination system also encouraged rote learning, rather than project work, positive attitudes and good values. Map work was cited as the weakest area of the geography syllabus – the section was compulsory, yet most schools lacked topographical maps. (Innes, 2012; Larangeria & van der Merwe, 2016) Hence, teachers experienced difficulties in teaching learners' spatial skills (Innes, 2012; Maduane, 2016; Larangeria & van der Merwe, 2016) which resulted in poor mapwork skills.

2.3.2 OUTCOMES-BASED EDUCATION IN SCHOOLS IN SOUTH AFRICA

An outcomes-based education (OBE) curriculum was introduced in South Africa in the early 1990s. This curriculum was based on a learner-centred learning paradigm, with an emphasis on output (outcomes) rather than input. Unlike traditional education, OBE stressed learners actively seeking and managing their own learning, with teachers leading and offering direction so that learners could navigate their own learning (Botha, 2010). In South Africa, there were numerous challenges as a result of outcomes-based education. The advent of OBE did not alleviate the unsatisfactory situation in schools- the problems of geography education continued unabated.

The introduction of OBE in the late 1990s placed school geography in South Africa in an unwarranted position (Binns, 1999) which worsened the already known problems (Binns, 1999; Botha, 2010). Despite its numerous advantages and benefits, OBE as an approach had some drawbacks in the South African context, and geography education was not immune to these issues. Some of the problems encountered by teachers with the OBE curriculum included the following:

- Language used on OBE

The Language which was used in OBE was difficult to understand by the teachers and the learners (Jansen, 1999). The critics of OBE, despite OBE's learner centredness, claimed that the language used was too complex to understand, unclear and, at times, confusing. Educators did not understand the language used in OBE and this made it difficult for them to implement OBE effectively in their classrooms. Manson (1999), in concurring with Jansen's observations, argued that the language and terminology of OBE was far too difficult. According to Manson (1999), the successful implementation of OBE was dependent on significant levels of in-service training for under-qualified educators. Without the involvement of the educator, OBE would be difficult to implement.

- Paperwork

Another challenge associated with OBE was that it was loaded with a lot of paperwork, which required educators to spend a lot of time doing clerical work, instead of teaching (Van Niekerk & Du Plessis, 2012). The curriculum required an endless amount of evaluation, a variety of forms that educators were expected to complete, portfolios that had to be compiled, and research assignments that had to be graded, all of which left educators with less time to prepare meaningful learning materials for learners. Thus, it was argued that educators were constantly tired, and administrative officers felt burnt out, to the detriment of their performance. Class size was also an issue, and in other countries where OBE had been implemented, the average learner-to-teacher ratio ranged between 9:1 and 16:1, with each teacher having an administrative officer who assisted with paperwork and evaluation. The South African ratio was 55:1 and subject teachers had no assistance in their lessons to help them deal with any clerical work (Taruvinga & Cross, 2009).

- Teachers as curriculum specialists

The other challenge of OBE was expecting teachers to be curriculum specialists. Teachers were regarded as professionals who were expected to achieve an overwhelming number of outcomes, and they had to figure out how they were going to achieve those goals in their particular educational setting. Every teacher was, thus, a curriculum specialist, even though they had not been trained in this role. This position was worse in rural schools, where few teachers had proper training, and most schools were poorly equipped, resource wise (Motseke, 2005). This led to differentiation between school contexts: thus, what was done at one school differed drastically from what was done at another. This, in turn, led to gaps in education between the learners from different school contexts (Moodley, 2013).

- Textbooks

Learner support materials were also lacking in many schools, more especially in rural areas. In many learning areas, learners were no longer supplied with textbooks. Portfolios were compiled and learners received notes in the form of loose-leaf pages (Van Eeden & Warnich, 2018) in particular subjects. Additionally, when learners had to study for tests and exams, they often realised that the information in these portfolios and on the loose pages were so inadequately presented that it was impossible to identify what should be learnt, and learners were unable to look for extra information in each topic due to a lack of textbooks (Van Niekerk & Du Plessis, 2012).

The National Curriculum statement 2002 replaced OBE and it sought to address and resolve the challenges of OBE. Further improvements to the NCS led to the revised national curriculum statement (RNCS) in 2006 and the Curriculum and Assessment Policy Statement (CAPS).

2.4 INTRODUCTION OF GIS IN THE GEOGRAPHY CURRICULUM AND IMPLEMENTATION

GIS was first introduced in high school geography in South Africa in 2006 (Raselimo, 2017). It was introduced as a section in the RNCS for geography on an incremental and systematic manner over three years, i.e., Grade 10 in 2006, Grade 11 in 2007, and Grade 12 in 2008. It also appears in the new CAPS for geography (Department of Education, 2010). The current CAPS encourages the use of GIS in the classroom. One of CAPS's objectives is to promote the use of new technologies in geography, such as ICT and GIS. Learners in Grade 10 must understand general GIS concepts as well as related geographic concepts such as object types, scale, and resolution (spectral and spatial) (Department of Education, 2010, p. 46). The functional parts of GIS are included in the Grade 11 curriculum, which include data collecting, satellite and remote sensing as digital data sources, pre-processing, and data processing. Grade 12 learners must comprehend more GIS functional features such as data management, data manipulation and analysis, geographic data, product development, and application. As a result, learners are expected to be proficient in geographic numeracy by applying GIS procedures and spatial statistics at the end of their education (Department of Education, 2003, p. 13-48).

Although the Department of Education (DoE) has been instructed to develop and implement the GIS curriculum in the country's high schools, it has failed to provide guidelines for its actual implementation in South Africa's diverse range of schools). It is claimed that a lack of proper curricular guidelines, teaching tools, and instructional guides has delayed GIS implementation even more, particularly in resource-poor institutions in the country (Breetzke, Eksteen, & Pretorius, 2012; Zondi & Tarisayi, 2020). As a result, private companies including Esri South Africa, Intergraph, and Naperian Technologies have developed instructional resources and hosted GIS in-service training sessions for curriculum advisors and teachers. Efforts made to alleviate some of these challenges include the establishment of GIS teaching and learning support materials such as Paper GIS (Breetzke et al., 2011), USB-GIS and I-GIS (Milson & Earle, 2008), multimedia applications (Balram & Dragićević, 2008), WebGIS and GIS tutorials (Hong, 2014), which all have the potential to ease GIS integration in the classroom. A limited number of workshops across the provinces of South Africa have been presented to equip geography teachers with GIS skills and knowledge. The educational material created comprises both paper-based and computer-based GIS tasks (Van Eeden & Warnich, 2018). The South African Department of Land Affairs has also participated in a number of programs to raise map awareness, and it is also assisting the Department of Education in introducing Geographic Information Systems (GIS) and promoting geography as a topic in schools (Breetzke et al., 2012).The Department of Land Affairs and Sol Plaatje local municipality run a program where the GIS technicians visit secondary schools in the townships to demonstrate to grade 12 learners and teachers how GIS works and to donate topographical maps, digital weather stations etc. to promote GIS implementation in schools.

2.4.1 CHALLENGES FACING GIS IMPLEMENTATION IN SOUTH AFRICA

Like in other countries where GIS was introduced in the school curriculum, GIS faces a number of challenges in South Africa. These challenges range from a lack of money to buy the required computers and software, to a lack of training and limited will among educators to embrace the new technology in the teaching of geography (Mzuza & van der Westhuizen, 2019; Zondi & Tarisayi, 2020; Mkhongi & Musakwa, 2020). Many schools, especially in rural areas were already at a disadvantage (suffer from low-technical applications); they do not have the computers required to operate this technology (Dube, 2020) which impacts on teachers' attitudes to GIS. The challenges faced in implementing GIS according to Fleming (2013, p.10) are summarised in Figure 2.1 and discussed below.

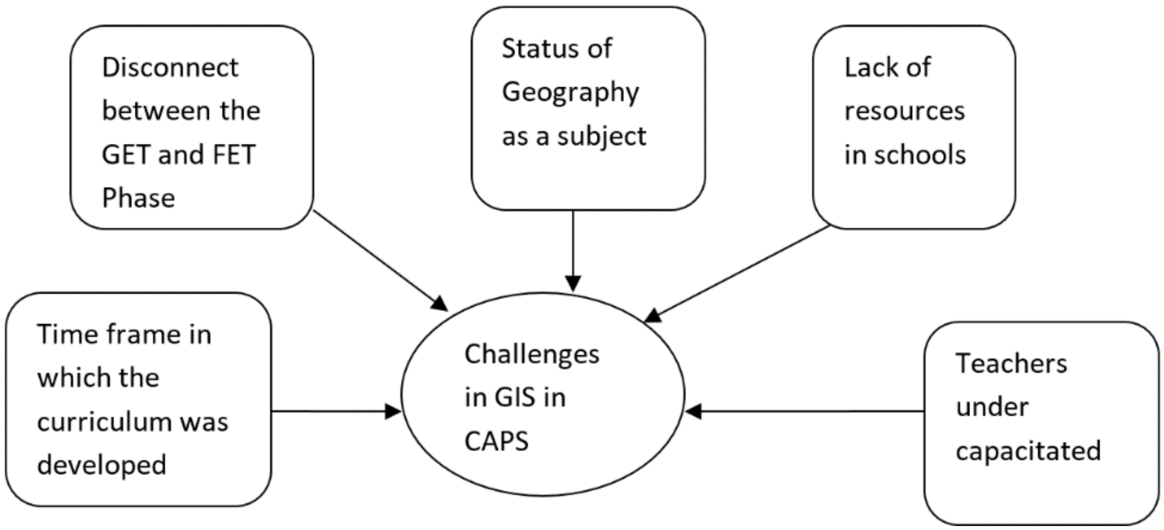


Figure 2.1: The challenges of implementing GIS

Source: Fleming (2013, p.10)

2.4.2 DISCONNECT BETWEEN THE GET AND FET PHASES AND LOSS OF THE STATUS OF GEOGRAPHY AS A SUBJECT

A challenge faced by geography teachers and learners is a lack of continuity between the general education training (GET; grades 0-9) and FET phases (grades 10-12) regarding basic map work skills. Fleming (2013) laments that basic spatial skills are not taught in the lower grades (Grades 5 to 9). This knowledge gap between the phases, it is argued, contributes to low achievement in map work in matric. Geography and history are combined into social sciences studies in the GET phase, which is often taught by a history teacher with little training in geography (Fleming, 2013; Maduane, 2016; Mukondeleli, 2018). If the social sciences teacher is trained in history or another subject but not geography, he or she will most likely focus on his or her area of specialisation, which will not help learners acquire the necessary spatial skills at a young age. It is suggested by Innes (2012) that this situation has contributed to declining numbers of learners taking geography in the FET phase. Should such learners who did not take geography or who lacked the spatial skills in the GET phase, take geography in Grade 10 then they are likely to struggle to master some of the spatial skills (Innes, 2012).

To exacerbate matters, many schools package geography against the sciences, so learners are restricted in their subject selection in the FET phase (Russell high school rule book, 2019). Learners who are not included in the science stream, even if they are good and interested in geography, are, thus, not accommodated. It must be noted that Geography as a discipline is very broad, and it includes physical geography and human geography. Physical geography, for example, includes sub-disciplines like climatology, geomorphology, biogeography, and hydrology, which are considered "pure" sciences. On the other hand, human geography encompasses sub-disciplines such as population geography, political geography, urban geography, economic geography, and cultural geography. So, in this case, learners who take the social sciences are denied the opportunity to continue with geography, because they fail to qualify to do natural science subjects, yet, they may be good in human geography (which is subdivided later on into specialisations at universities and colleges). Fleming (2013) also reports that there is a disconnect between the geography taught at high school and that which is taught at tertiary institutions, in terms of content and alignment, and this makes geography a less interesting subject. It is further reported that if these disconnections could be ironed out, geography as a discipline could be more appealing and interesting to learners (Akinyemi, 2015). Also, Goodchild and Palladino (1995), as cited in Zondi and Tarisayi (2020, p.2), stated that geographic information systems (GIS) can inspire learners to pursue careers in science and engineering, implying that schools should provide more subject options. This disconnect between the phases and other problems faced by the schools and teachers has resulted in poor performance of GIS questions in paper 2 in the matric examination. The following section discusses the performance of learners in geography.

2.4.3 PERFORMANCE TRENDS IN GEOGRAPHY (2016 – 2020) IN THE NORTHERN CAPE PROVINCE

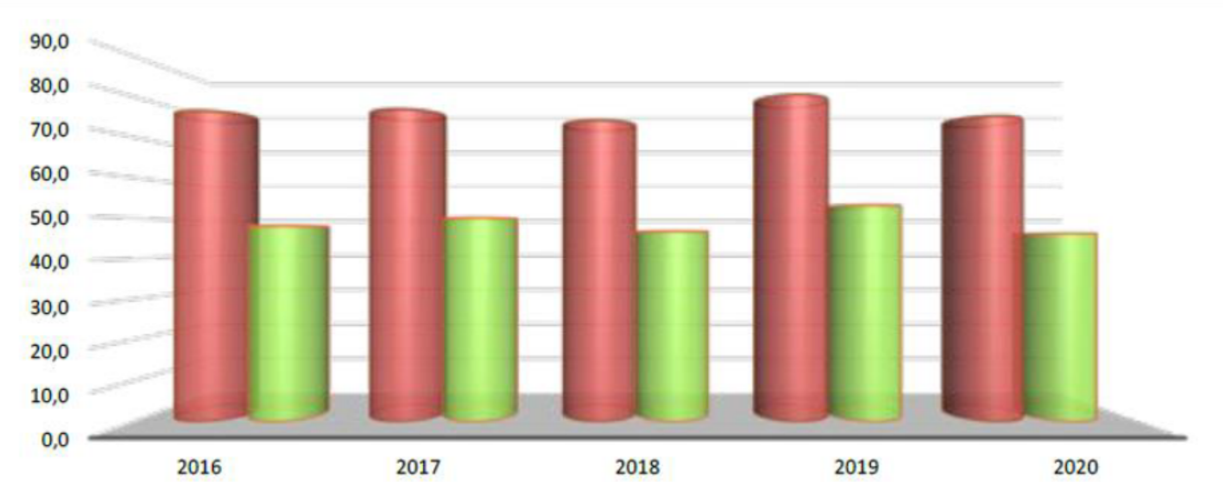
The number of candidates writing Geography increased by 15 822 in relation to the 2019 enrolment. (Northern Cape Department of Education (Department of Education (DoE), 2003). Table 2.1 shows some of the statistics of the province.:

Table 2.1: Overall enrolment and achievement rates in Geography

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2016	302 682	231 641	76,5	145 726	48,1
2017	276 771	212 954	76,9	138 704	50,1
2018	269 621	200 116	74,2	126 011	46,7
2019	271 807	218 821	80,5	144 755	53,3
2020	287 629	216 467	75,3	132 955	46,2

(source: Department Education (DoE). (2020)

As indicated on Table 2.1, from 2016 there was a decline in the number of learners who wrote geography in matric. From 2019 to 2020 there was an increase of 15 822 learners who wrote the geography examination in the province. The performance of geography as a subject is still a course of concern in the province. It is disappointing that after significant improvement in 2019, the number of passes at the 40% and 30% levels decreased by 11 800 candidates and 2 354 candidates respectively (Department of Education (DoE), 2003). At the 40% level, percentage passes were achieved by 53,3% of the cohort compared to 46,2% in 2020, while at the 30% level, the percentage passes declined from 80,5% to 75,3% (Northern Cape Department of Education (Department of Education (DoE), 2020). In the report it was noted that learners are improving in other sections of geography but lacking in GIS section. The report indicates that in the shorter response questions, candidates are showing an improved understanding of Geographical processes and they can provide better explanations than previously. They do, however, continue to struggle with the questions on map calculations and GIS in Paper 2.



	2016	2017	2018	2019	2020
% achieved at 30% and above	76,5	76,9	74,2	80,5	75,3
% achieved at 40% and above	48,1	50,1	46,7	53,3	46,2

Figure 2.2: Overall achievement rates in Geography (percentage) (source: Department of Education (DoE). (2020)

2.4.4 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 2 IN GIS SECTION

Although the report stated that there was an improvement in performance in paper 2 in the province, a close look at the pass rate percentage for question 4 where GIS concepts are examined shows that the average pass percentage for that question was 41% (Department of Education (DoE), 2020). This low pass rate in the GIS questions is not unique to Northern Cape province. Similar trends were evident in Eastern Cape of 2018. The overall performance in the GIS question 4 improved from 40.9% (2017) to 55% (2018). The worst performed sub-questions were Q4.1.2, 4.2.3 and 4.3.1. (Somera, 2018). The report further stated that learners' performance in the question 4 (GIS section) was relatively better than the previous year. There was an improvement of the pass rate by 14.1% from the previous year (Somera, 2018). Considering the problems that Geography teachers and learners alike have been encountering over the years there has been some improvement.

2.4.5 LACK OF FUNDING AND TRAINING

Another challenge faced by countries all over the world, is a lack of funding that jeopardizes implementation and rollout of GIS in schools (Nxele, 2007; Fleming, 2016; Zuma, 2016; Tarisayi, 2018). In developing countries, such as South Africa, a lack of funding and institutional commitment has prompted the implementation of GIS in a piecemeal fashion. Decision makers in underdeveloped nations, according to Reinecke (2005), must be taught about the strategic importance of GIS in order to build institutional capacity in their organizations and commit ongoing financing to GIS. It is further contended that schools in South Africa are not funded adequately. Most schools, especially those in rural areas, do not have electricity and some schools lack adequate classrooms, thus, it will be impossible to expect such schools to have well-equipped computer laboratories with GIS software (due to crime for example, the ongoing theft of computers from schools) (Mabuza, 2019).

Another issue is a lack of strategy or steady efforts to train and assess geography teachers in GIS. The existing ad hoc training and assessment is ineffective and lacks inspiration (Innes, 2012; Maduane, 2016). Most schools in South Africa only provide a rudimentary introduction to GIS, which is not adequately taught (Zondi & Tarisayi, 2020). The learners are not taught the practical part of GIS which is the main aspect of GIS (Dube, 2012; Ahiaku & Mncube, 2018; Malatji & Singh, 2018). It is asserted that there is limited research on ascertaining how schools in rural areas are expected to teach GIS when they do not have a single topographic map in the school (Fleming, 2013; Maduane, 2016). It is clear that more research is required to find out what teachers can do to help improve the situation. While GIS has been used in industry and the corporate world for several years, it has only recently been introduced into schools and the country faces challenges in developing a national skills strategy that will address GIS issues across all sectors of the country, including higher education. Dube (2012), Ahiaku and Mncube (2018), Malatji and Singh (2018), Tarisayi (2018), and Mzuza and van der Westhuizen (2019) all focused on teachers' perspectives on GIS implementation in high schools agreeing that teachers encounter significant problems while teaching GIS. Mzuza and van der Westhuizen (2019) further claimed that only a few workshops on GIS were held in the four centres in Gauteng in SA in 2006, which indicates inadequate training, given that most teachers in rural areas have limited or no access to computer technology. Malobola (2021) also asserted that teachers in the Eastern Cape encounter challenges when teaching Geography and GIS due to lack of resources more especially rural remote locations where they are teaching.

2.4.6 LACK OF RESOURCES AT SCHOOLS

Many South African learners are not able to enjoy access to learning materials (Manik & Malahlela, 2018; Mzuza & van der Westhuizen 2019; Zondi & Tarisayi, 2020). According to a survey carried out by the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ III), the typical Grade 6 learner was in a school where only 45 percent of learners had reading books and 36,4 percent had mathematics textbooks in 2007. (Moloi & Chetty, 2010). A lot of studies show that supplying proper textbooks can considerably improve educational achievements, according to Fuller (1999), referenced in the South African Human Rights Commission, 2014). It is frequently argued that if GIS has even a remote chance of being correctly implemented in schools, learners must have textbooks and other learning and study materials that can improve their knowledge and skills in GIS (Breetzke, Eksteen & Pretorius, 2011; Innes, 2012). Most CAPS-approved geography textbooks are printed in colour, and there are extensive teachers' guides and digital resources. To use these resources and to have access to the available Web 2.0 tools and support groups, such as the SA Geography Teachers' Network mailing list, teachers ideally need their own laptops. Access to hardware and software (computers and GIS software) remains a challenge at many schools in South Africa (Carolissen, McPherson & Kleyn-Magolie, 2006; Sedibe, 2017; Innes 2012; BUSINESSTECH, 2021). Schools in the Eastern Cape, KwaZulu-Natal, and Limpopo were the worst affected, according to data from the National Education Infrastructure Management System (NEIMS) from March 2018. Even at well-resourced schools, access to computers is restricted by the timetable, and there are competing ICT demands of other subjects (Fleming, 2012). Few schools in either urban or rural areas have access to computers and internet connections. Many public schools found in both urban areas and rural areas rely on government grants for funding, which is not enough to cover their daily operations, and the purchase of computers. Studies indicate that only former Model C schools,[1] those in quintile 4 and 5, and private schools, can afford to buy computers and pay for a regular internet connection (Innes, 2012; Zondi & Tarisayi, 2020; Mkhongi & Musakwa, 2020). However, the reality is that GIS is not examined practically in the matric exit examination in South Africa and it is not compulsory for Geography teaching to take place through GIS, which means that such schools find no reason to establish GIS laboratories, and this continuously compromises the effective teaching of GIS.

[1] Former Model C schools: These schools were established in the 1980s and 1990s. They are semi-private structures, with decreased funding from the state, and greatly increased autonomy. These schools have school fees, though teachers are paid by the state -- the school fees paid by parents serve as a top-up. These schools pay top teachers of important subjects well and may offer high quality education at a reasonable cost.

2.4.7 THE QUALITY OF A TEACHER

Teachers are critical in introducing innovative ideas into the educational system and the wider world (Höhnle, Fögele, Mehren & Schubert, 2016; Maude, 2018; Collins & Mitchell, 2019; Curtis, 2019). As a result, it is critical that teachers receive training in these innovations so that they can pass on their knowledge to learners. It is essential that all possess instructional/ intervention skills which are directed towards maximising the learner's potential. One of the first criteria that parents, teachers, school officials, and researchers look for when evaluating schools is teacher quality (Holland et al., 2011). As a result, it is critical that teacher quality and teaching quality be improved. In South Africa, for example, the National Education Policy Act provides criteria for recognizing and evaluating qualifications for teaching positions (Act 27 of 1996). Cherian (1996) cited in Maphoso and Mahlo, (2015) contended that there is a noteworthy association between teacher's knowledge of the subject which he/she teaches and the attitude towards the subject. Variation in teacher quality, according to Koedel (2007), is a significant influence on learner accomplishment. Teachers are educated at colleges and universities, which play a significant role (Maphoso & Mahlo, 2015). For example, most industrialized countries, including the United States and Canada, are actively working on ways to improve web mapping curriculum in higher education (Sack, 2018; Collins & Mitchell, 2019). Although Southern African countries lag behind in terms of geospatial web technology, they are making progress (Amade, Painho & Oliveira, 2018; Mzuza & van der Westhuizen, 2019; Mkhongi & Musakwa, 2020; Zondi & Tarisayi, 2020). GIS is only taught in teacher-training universities and secondary schools in some of African countries such as South Africa, Botswana, and Malawi. GIS is not taught in some teacher-training universities and secondary schools in some countries, such as Zambia and Namibia and is only taught at universities or departments that do not train teachers (Mzuza & van der Westhuizen, 2019). In Angola, Mozambique, Swaziland, and Lesotho, GIS is not taught in universities (Mzuza & van der Westhuizen, 2019). The authors assert that countries that are teaching GIS at both tertiary and secondary levels have discovered that GIS can help with policymaking, critical thinking, inquiry-based learning, and learner-centred learning, all of which can improve educational quality.

However, despite all these efforts made in other countries more especially in Southern Africa, the challenges remain, that some tertiary institutions that train teachers do not teach any content relating to GIS at first-year level (Osman & Petersen, 2013). GIS modules are taught by science faculties at universities where they are available, rather than education faculties where teachers are trained. It was asserted that there are geography teachers in South Africa who have only learnt geography for a year and, consequently, have no formal GIS training (Mkhongi & Musakwa,

2020) As such, the teachers who graduated from these institutions of higher learning will lack the grounded knowledge in the subject they will be teaching in high schools currently.

2.4.8 THE QUALIFICATIONS OF TEACHERS

According to the literature, there is a link between teachers' academic qualifications and learner achievement. Research on the connection between teachers' qualification and learners' performance showed that there is a strong relationship (Richardson & Watt, 2008; Antony & Elangkumaran, 2020). Research by Richardson and Watt (2008) on qualitative analysis in mathematics and reading showed that there is a strong correlation between teacher qualification and learner academic achievement. Learners who were taught by teachers who majored in mathematics outperformed those who were taught by teachers who had no mathematics qualifications (Mupa & Chinooneka, 2015). Baloyi (1996), as cited by Maphoso and Mahlo (2015), noted that the main problem in most African schools was the lack of teaching qualifications. Maphoso and Mahlo (2015) also stated that in the past, the South African education system strengthened the social structure by disempowering both teachers and learners. Teachers who were underqualified, had little knowledge of the subject matter, and lacked a creative teaching style. As a result, they had few options for teaching methods other than traditional methods such as lecturing and questioning. The disabling environments which teachers find themselves in, tend to limit them in the pedagogical approaches they can use to teach for example, GIS in schools (Engelbrecht et al., 1999). Most of the teachers find it difficult to use learner-centred pedagogical approaches such as field work, project assignment teaching method, group work just to mention a few (Du Plessis, 2020). Studies indicate that this is due to time constraints for preparation of lessons and at times some schools do not have enough resources to apply such teaching methods. The classroom layout and availability of technological resources such as overhead projectors, GIS laboratories, GIS software etc. play a pivotal role in choosing the pedagogical approach a teacher can use to deliver a lesson more especially in a specialised field like GIS (Du Plessis, 2020).

Teachers who are highly qualified are known to perform better than those who do not possess the same qualification (Maphoso & Mahlo, 2015). According to Lim (2007), as cited in Holland, et al., (2011), argued that content area majors such as mathematics and science courses that need advanced skills to improve learner test scores are more effective than other subject areas. Antony and Elangkumaran's (2020) research in Sri Lanka's Trincomalee District on the impact of teacher qualifications on learner achievement in science discovered a strong relationship between teacher qualification, subject specialization, and pupils' academic qualification. Unanma, Abugu, Dike, and Umeobika (2013) investigated the connection between instructors' academic qualifications and learners' academic accomplishment in Chemistry and discovered that there is a link between teachers' academic qualifications and learners' academic achievements. This finding supported the findings of Adeyemo (2013), who examined the performance of English Language Teachers (ELTs) and Teachers with Formal Education (TFEs) at the secondary level in public high schools. According to Adeyemo's findings, learners who received instruction from ELTs outperformed those who received instruction from TFEs in the final exams. Boyd, Grossman, Lankford, Loeb, Wyckoff, (2008), as cited by Maphoso & Mahlo (2015), also stated that improvements in teacher qualifications, particularly among those in low-income schools, appear to have resulted in higher levels of learner achievement. A well-trained teacher who is knowledgeable about his or her subject, according to Maphoso and Mahlo (2015), will be able to recognize the weaknesses and strengths of his or her learners and work to make learning and teaching easier.

Contrary to these views, Thompson (2014), points out that qualification alone is not a guarantee of good teaching and as such teachers' academic qualifications alone do not guarantee the high academic achievement of learners. Teachers should know how to organise their classes and their lessons in a manner that will help learners to learn effectively. Furthermore, highly qualified teachers, according to Thompson (2014), do not necessarily teach well-designed, standard-based classes. After realising a lack of competence in GIS training amongst high school teachers in geography, the Department of Education introduced workshops, where the teachers were trained in GIS. However, GIS workshops that have been presented in many provinces in South Africa yielded varying degrees of success. Hence, as noted by Fleming (2015), there are a range of interventions which have been done in various provinces in trying to capacitate the teachers. For example, a number of GIS teacher training workshops in the Metro South district in the Western Cape resulted in a 6% improvement in the geography results (Fleming, 2015). In order for workshops to be effective there is a need for such workshops to be linked with SETA[2]-approved modules and teachers need to be incentivised, so that they will find the need to attend them. This sadly implies that teachers will only further their skills and attend workshops for extrinsic reasons.

[2] A skills development course that is SETA (Skills Education Training Authority) accredited means that it has been approved by one of the 21 industry-specific SETAs. Each SETA establishes specific training provider standards, which ensure the quality of a SETA-accredited course.

2.4.9 TEACHERS' EXPERIENCES AND QUALIFICATIONS AS FACTORS IN LEARNER ACADEMIC ACHIEVEMENT

Teachers' qualifications and teachers' teaching experience play important roles in learners' academic achievement (Boyd, Grossman, Lankford, Loeb & Wyckoff, 2008; Maphoso & Mahlo, 2015; Antony & Elangkumaran, 2020). The background of teachers, such as qualifications and years of teaching experience, has a substantial impact on learners' academic progress in mathematics.

The number of years a teacher has taught is referred to as a teacher's experience (Antony & Elangkumaran, 2020). Teachers with more than six years of teaching experience outperform teachers with a lesser number of years in the teaching profession. Learner achievement rises with teacher experience and falls with less than two years of teaching experience (Buddin & Zamarrow, 2009; Wong, 2013; Musau & Abere, 2015; Antony & Elangkumaran, 2020). It is not always evident, however, that teachers' qualifications and teaching experiences have a positive impact on learners' academic progress. The changes in the geography curriculum could make teachers appear incompetent in some topics for example, in GIS in geography. This notion was supported by the Koedel study (2007) which stated that a teacher's qualifications cannot be solely responsible for learners' performance. Kimani et al (2013) discovered that a teacher's professional credentials and teaching experience were not significantly related to their learners' academic achievement, which is consistent with Koedel's findings.

In addition to the challenges mentioned above, Singh (2004) identifies politics as another factor that acts as a stumbling block to the growth of GIS. In this case, political decisions can determine where resources, such as money and school grants, should be allocated. If a school or region does not support the leadership of the day, the infrastructure in that region can suffer from a lack of financial support and, as a result, GIS technology may not be able to diffuse as expected. Furthermore, Singh (2004) contends that poverty and illiteracy are major issues in most developing countries. South Africa, as one of these developing countries, also grapples with problems related to poverty and low levels of literacy. Poverty has an impact on the rate of GIS diffusion because the cost of technology must be balanced with other priorities such as healthcare and food security. Also, South Africa has 11 official languages, making the provision of GIS software in multiple local languages, extremely difficult.

The school curriculum, according to Singh et al. (2016), includes basic GIS theory but does not include training in the practical application of GIS using computers. While a fraction of public schools has computers for learners to utilize, not all have the finances to purchase the essential software to effectively teach GIS (Singh, 2004). As a result, many people see GIS as a bridge between paper-based map study and the IT resources that are still not available for teaching in most South African schools.

2.4.10 TEACHERS' SUBJECT KNOWLEDGE

Subject knowledge is another variable that one might link to teacher effectiveness in the class. Research by Antony and Elangkumaran (2020) showed mixed results. Wilson and Floden (2003) discovered, as cited by Antony and Elangkumaran (2020), that there appears to be a trend in mathematics where learners who were taught by teachers who majored in mathematics or had a mathematics education degree performed significantly better than learners who were taught by teachers who did not major in mathematics. Subject knowledge is important for the teacher's explanation of concepts in greater depth and building confidence in his approach and articulation (Yetkiner Özel & Özel, 2013). According to Ademulegun (2001) cited in Kiamba, Mutua & Mulwa (2018), learners taught by instructors who are more qualified and experienced in terms of the topic did better than learners taught by teachers who are significantly less qualified and experienced in terms of the subject. A teacher's subject knowledge is "essential and extremely critical" in the classroom (Kiamba, Mutua & Mulwa, 2018, p. 8052). Their research further revealed that a teacher's intelligence and resourcefulness determine the teachers' ability to engage learners in the learning process, their area of research and expertise influence the subject knowledge of learners' academic achievement. A teacher's subject knowledge is "essential and extremely critical" (Kiamba, Mutua & Mulwa, 2018, p. 8052). They explained that it would be unusual to expect a teacher to plan a lesson on, writing a science report and evaluating related assignments if the teacher is unfamiliar with writing about science. Jadama (2014) noted that, a teacher who is unfamiliar with the subject can pass on incorrect information to learners, read texts uncritically, and even change the content. Teachers will not be able to answer difficult questions about the subject they teach. Teachers who have a thorough mastering of the subject they teach are in a better position to plan their lessons effectively and evaluate their learners' work. Subject knowledge enables the teacher to educate successfully, utilizing a variety of teaching approaches, to ask diverse and alternative questions, and to clarify misconceptions regarding subject matter (Jadama, 2014). The acquisition of curriculum goals will be hampered if content knowledge and pedagogical content knowledge are lacking (Kimosop, 2015).

The attitudes and expectations that learners bring into the classroom may influence the teacher's subject matter understanding (Kiamba, Mutua & Mulwa, 2018). Teachers' inability to simplify content to help learners understand can be hampered by a lack of in-depth knowledge of the subject (Jadama, 2014). Finally, limited time is allocated for teaching GIS in the curriculum. It appears that the 14 hours over a 3-year period for the geography teacher is not enough for them to introduce the needed practical component of GIS (Kerski, 2003; Fleming, 2012).

2.4.11 EFFORTS TO DIFFUSE GIS TECHNOLOGY IN SOUTH AFRICAN HIGH SCHOOLS

The introduction of GIS in 2006 as part of the Grade 10 geography syllabus has not resulted in Geography curricula changes in every university undertaking initial teacher education. Universities that train teachers may offer GIS as an elective, while others do not even offer it to student teachers training to become geography teachers such as in the Eastern Cape province (Malobola, 2021). Another example is that GIS is offered in the second year, only as an introductory module for the B.Ed. programme of Sol Plaatje University in the rural Northern Cape Province, which opened its doors to learners in 2014.

In 2015, the Northern Cape Financial Services Directorate received a request from the Northern Cape Department of Education to fund training workshops for geography teachers in the province in order to address a problem that the department was facing. In the geography Paper 2 of their final exams, Grade 12 learners did not attempt any GIS-related exam questions (Northern Cape Department of Education (Department of Education (DoE), (2020). This is not the only province experiencing this challenge. A report from the Eastern Cape also showed that learners experienced the same challenges as noted in Northern Cape province (Somera, 2018). GIS-related questions account for 20% (15 marks out of 75) of the total marks in the paper 2 examination paper – a significant portion that can mean the difference between a pass and a failure (DoE, 2014). After securing funding, the Department of Education in the province recruited people who could train geography teachers in the Frances Baard District of the province. The request asked for topographical and orthophoto maps, as well as GIS software and training for officials, teachers, and learners in rural areas. The training took place in the Frances Baard District and was scheduled to be rolled out across the province in 2018, after I had completed the data collection for this study. The intervention was based on the realisation that both geography teachers and learners lacked exposure to the practical side of GIS, about which questions are asked in the GIS section of the exam paper. Learners are asked to apply the theory to the practice of a working environment. After the workshop, which was facilitated by two GIS technicians and one manager from the Sol Plaatje municipality, a DVD was created and sent to 36 secondary schools in the Frances Baard District. The DVD was included as part of the educational materials to help learners understand the subject from a practical standpoint. The DVD includes GIS practical exercises and demonstrations that can be used to help learners understand the practical application of GIS in their geography curriculum.

2.5 PHILOSOPHIES UNDERPINNING TEACHING AND LEARNING

There are numerous teaching and learning philosophies, and these are relevant to the current study of how GIS is taught in schools. These philosophies include behaviourism , cognitivism, constructivism, and, more recently, the social constructivist approach, which have evolved significantly over the last few decades. Table 2.2 presents philosophies that are used to explain the underpinnings of teaching and learning.

Table 2.2: Philosophies of teaching and learning (Adapted from Singhal, 2017, p. 5124)

Philosophies and theories	**Implications for teaching and learning**
Behaviourism (based on behavioural psychology) • Skinner • Watson • Bandura	The teacher will present facts and skills. The teacher knows the answers: The teacher is the "expert" in a teacher-centred approach. There are absolute answers in all areas of knowledge. In their approaches to learning, learners employ mastery patterns.
Cognitivism (based on gestalt psychology) • Dewey • Piaget • Bruner	The teacher provides a framework for learners to build their own knowledge. Active learning is a collaborative effort between the teacher and the learner. Audio and video recordings, graphic organizers, and flow charts all function well with this philosophy.
Humanism • Maslow • Rogers	The teacher provides a plethora of resources from which learners can select. Interpersonal skills have been honed to perfection. Learners become emotionally invested in their education. In order to learn the content, learners attempt to understand another person's point of view.
Vygotsky's constructivism is based on gestalt psychology and cognitivism.	Learners derive knowledge from prior and current experiences. Education is more than just preparation for life; it is life itself. Teachers must meet learners where they are and help them

Philosophies and theories	Implications for teaching and learning
	progress through an experience that they (learners) value at the time. Learners need more time to build a concept than they do to be told one. For this situation, hands-on activities are ideal. The axiom is that you learn by doing. Teachers create problem-solving activities and assignments. The facilitator's role is to provide initial support and then gradually reduce it as learners gain competence and their ability to take on more responsibility (scaffolding).

2.5.1 BEHAVIOURISM

The proponents of this theory are of the notion that behaviour is moulded by forces that originate in the environment. They think that learning is made up of facts, exercises, and practices, and that learning is evidenced by changes in learners' behaviour. Behaviourism is linked to teacher-centred pedagogy: The teacher is at the centre of everything that is happening in the classroom and the teacher is expected to have all the answers (Singhal, 2017). In this case, the learners are regarded as people who are waiting to be taught, or as bowls that are waiting to be filled by the teacher (Johnson, 2009). Singhal (2017) explains that exercise and repetition are the most important components of this philosophy. The exercises that the teacher gives and repeats during the lesson aid in the development and maintenance of stimulus-response connections. To offer the necessary frequent repetition for efficient reinforcement of response patterns, behaviourist teaching approaches mainly rely on "skill and drill" activities (Singhal, 2017, p. 5126).

2.5.2 GIS IN EDUCATION AND THEORIES OF LEARNING: CONSTRUCTIVISM

Constructivism, as a psychological and educational theory, has its roots in Piagetian developmental psychology. According to this theory, people create their own understanding and knowledge through experiencing and reflecting on things (Singhal, 2017). Learning is determined by how each individual learner examines a situation and draws his or her own conclusions (Ncube, 2018). In essence, learners should be given opportunities to construct their own knowledge. The teacher's role in this situation is to act as a facilitator, guiding learners as they construct their own knowledge. As a result, learning is heavily reliant on the learner's interaction with the world in which the learner lives (Ncube, 2018). Constructivist learning, according to Venkatesh & Davis, (2000, p. 65), is "a process of maintaining an adequate fit with one's ever-changing circumstances rather than creating an internal model of an external reality". Learning is no longer considered as a process of taking or absorbing knowledge, but rather as a process of adapting to one's changing circumstances, because the learner's ability to modify the way he or she thinks in reaction to the environment positions the learner at the centre of the learning process (Ncube, 2018).Teachers will be able to use technology such as GIS to empower learners to participate in knowledge creation rather than simply absorb knowledge from teachers as a result of this shift in geography education (Ncube, 2018).The CAPS document asserts that GIS (as an ICT tool in geography) should be integrated into the lessons of other topics of Geography. The reasoning is that learners can be able to benefit and keep abreast of the modern technology.

In order to accomplish this in a GIS lesson, teachers should ask questions, investigate, and assess what learners know. To put it another words, teachers must create environments and scenarios that allow learners to question and connect new knowledge to prior knowledge.

2.5.3 SOCIAL CONSTRUCTIVISM

Constructivism puts a strong emphasis on the learner's social and cultural surroundings (Ncube, 2018). Social constructivism is based on cultural learning and teaching: Culture is emphasised as the most important vehicle of learning. People learn through cultural integration (Singhal, 2017; Ncube, 2018). People use culture to pass on new knowledge to the younger generations; this can happen when people socialise, and, in the process, knowledge is passed from generation to generation. Interaction with adults helps young children develop their thinking abilities. Social constructivists value the context in which learning takes place as well as the social circumstances that learners bring to their learning environment (Singhal, 2017). When teaching GIS, learners can be socialised into learning the technology, if the physical resources such as GIS laboratories, GIS software, internet connectivity etc. are available. Learners eventually acquire knowledge and skills in GIS through their day-to-day interaction with GIS and spatial software that is available. In respect of the three theories/philosophies of learning highlighted in Table 2.3, constructivist theories, as postulated by Dewey, Piaget, Bruner and, of late, by Vygotsky, resonate well with the way GIS should be learned and taught because GIS requires hands-on experience, involving learners in the classroom being guided to learn GIS by doing and solving real problems that affect the environment. The Geography FET curriculum envisions learners in the classroom being able to discover information and draw their own conclusions founded on what they have learned. As a result, the teacher's role is to instruct the learner on how to use GIS so that learning can occur. Extrapolating from the curriculum, it is expected that the teacher creates an environment in a GIS lesson that allows the learner to explore, discover, and make sense of the spatial problem/s. The teacher has to stimulate the learners to become critical and spatial thinkers. In addition, learners should be socialised into the use of GIS when they work to solve spatial problems. This of course is only feasible if the teacher is knowledgeable about the content and the pedagogical approaches which are best suited to transmit the knowledge to learners. However, the reality is that GIS is a new topic that has been introduced to the geography curriculum recently and, as such with limited training initiatives, most teachers arguably, lack knowledge on how to teach it (Mkhongi & Musakwa, 2020). A constructivist approach to teaching geography places critical thinking at its core. The use of GIS in other Geography classes encourages learners to learn through discovery and depends on how the teacher engages the learners with the available GIS technology (Ncube, 2018). The shift from cognitivism to constructivism ushers in a considerable extension of the learning environment's dimensions, where the boundaries are articulated in terms of the learner's desire and aims rather than the instructor's plans. This is critical to the study because, as Ncube (2018) asserts, contextual factors influence how the teacher integrates GIS into the classroom teaching of geography. When combined with other learning theories such as behaviourism and cognitivism, constructivism as a learning theory becomes more understandable.

2.6 PEDAGOGY

The study of teaching and how knowledge is presented and delivered to a learner is referred to as pedagogy in Greek (Maclellan, 2008). It is the development of an educational process that results in the learner gaining knowledge. Pedagogy is more specifically concerned with the strategies, methods, and techniques associated with teaching and instruction (Barton, 2019. p. 1). The theory and practice of teaching, teaching tactics, teacher-learner interaction, and instructional content used to make content understandable to the learner are all included in the concept of pedagogy. In the field of education, pedagogy refers to the method through which a teacher instructs their learners, taking into account past knowledge, classroom setting, end goals, and other aspects.

2.6.1 PEDAGOGICAL APPROACHES

One of the critical questions of this research relates to the pedagogical approaches used by the geography teacher to teach GIS in high schools. This section discusses the general pedagogical approaches used by geography teachers to teach geography and GIS as is evident in the literature. The pedagogical approaches used in geography generally are also used to teach GIS, which is why I start by discussing the pedagogical approaches (including teaching methods and strategies as per Barton, 2019 above) used to teach geography broadly. This synthesis of disparate techniques has a considerable impact on how teachers integrate GIS in the Geography classroom (Ncube, 2018).

The definition and understanding of pedagogical approaches given in Chapter 1 will be used in this section, to maintain consistency throughout this research. To summarize, pedagogical approach refers to "interactions between teachers, learners, the learning environment, and learning tasks." (Murphy, 2008, p. 35). In this research the concept of pedagogical approach is used as an encompassing term which covers the methods used in teaching geography and GIS in particular, the techniques and strategies used by teachers when teaching in the classroom. These pedagogical approaches can be grouped into either teacher-centred pedagogy or learner-centred pedagogy (Murphy, 2008). The next section discusses the differences between teacher-centred and learner centred pedagogy. As illustrated in Figure 2.3, teacher-centred pedagogy places the teacher at the centre of everything.

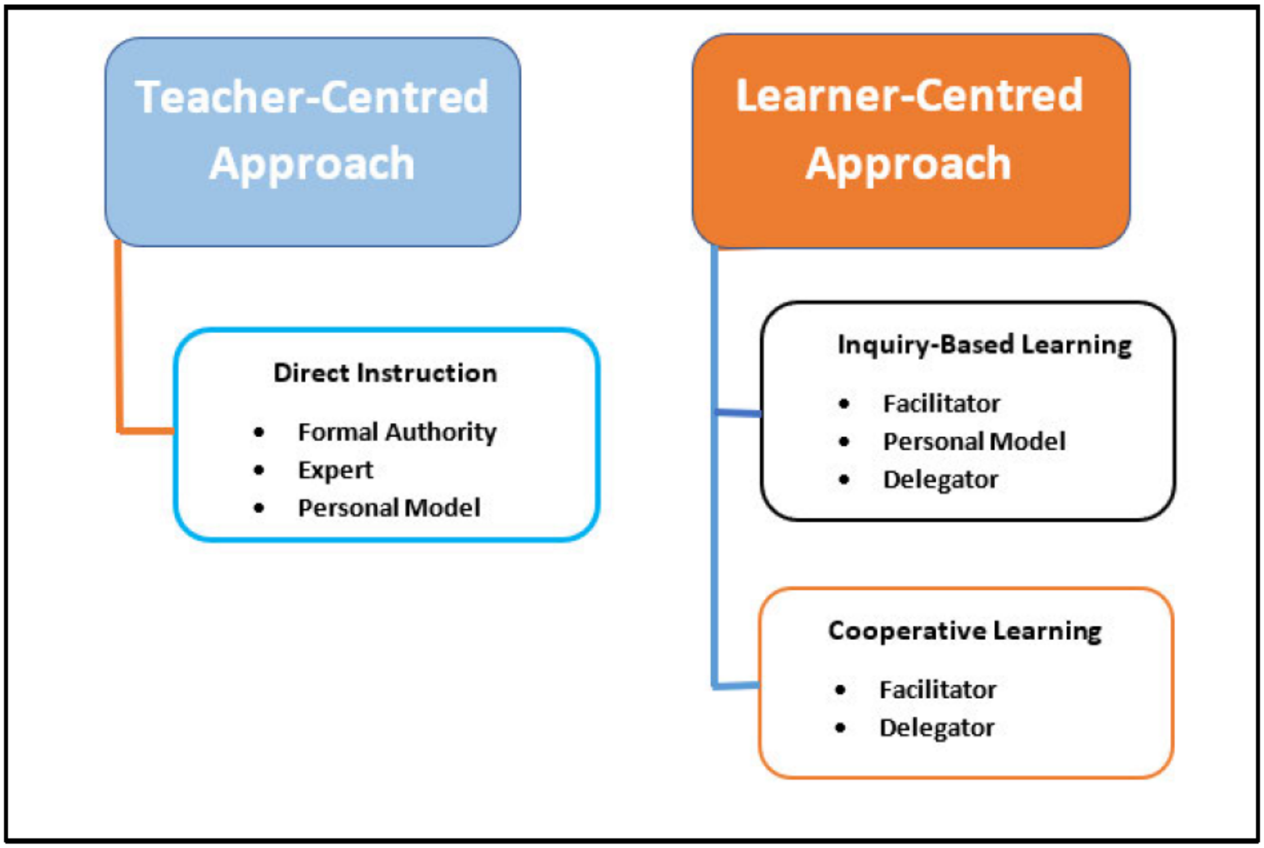


Figure 2.3: A comparison between teacher-centred and learner centred learning.

Source: Grarrett 2008.

To further analyse the differences between teacher-centred and learner-centred, (Table 2.3) below, summarises the differences between these two approaches.

Table 2.3: Teacher-Centred versus Learner-Centred

Component	Learner-centred	Teacher-centred
Leadership in the classroom	Leadership is shared	Teacher is the sole leader
Management in the classroom	Management is a form of guidance	Management is a form of oversight
Inspiration	Value driven and helps to improve learners' interest, innovativeness, and it incorporates learners' earlier learning regarding the matter knowledge on the subject.	It is drawn from the teacher and is focused on lesson
Learning processes in the classroom	Live classroom learning process. Participatory methodologies are used, for	The process is passive and the teacher dominates it; learners sit unobtrusively, taking notes

	example, little gathering dialog, think-combine offer, tasks and fieldtrips are used	from the teacher's address. Collaboration in the classroom is insignificant.
Teacher and learners' relationships in the classroom	Fluid relationship with the end goal that both the teacher and the learners learn from each other	Authoritative sort of relationship, where the teacher is the fountain of information.
Classroom atmosphere	Democratic, casual, shared, and supportive.	Authoritative, tense, low input from the learners,
Assessment of instruction	Mainly developmental appraisal where the teachers and learners together survey and assessment is jointly done. Teachers use assessment results to illuminate their learners.	Classroom assessment is completed by teachers Teachers utilize assessment for evaluating.
Responsibilities in the classroom	Learners share share in classroom responsibilities	Learners are allowed limited responsibilities.

Source: from Msonde (2011, p. 35)

2.6.1.1 TEACHER-CENTRED PEDAGOGY

Teacher-centred pedagogy necessitates that the teacher be at the centre of everything that occurs in the classroom. Learners are expected to listen and asked questions and give answers when they are asked to do so. Common teaching methods associated with teacher-centred pedagogy include class explanations, questioning, lectures and discussions (Westbrook et al., 2013; Otukile-Mongwaketse, 2016; Ameliana, 2017; Serin, 2018). In teacher-centred pedagogy, the teacher leads and is seen as the one who enforces rules in the classroom. In a teacher-centred pedagogical approach, the teacher is responsible for ensuring that learning activities are planned and structured, as well as determining the time and method for task completion (Westbrook et al., 2013; Maduane, 2016; Serin, 2018). The primary roles of in the classroom are to state, explain, and model the lesson objectives, as well as to focus the learners on the tasks at hand. The teacher responds to learners through direct feedback, and by providing yes or no answers (Mascolo, 2009, p. 26). Teacher-centred pedagogies are modelled on an active teacher and a passive learner (Otukile-Mongwaketse, 2016; Attia, 2017; Serin, 2018).

i) LECTURE METHOD OF TEACHING

The term lecture is derived from the 14th century Latin word lectus, which means "reading aloud, “that which is read” (Paris & Winn, 2014, p. 45). Lecturing is a teaching method that evolved over the years. It entails an instructor delivering an oral presentation to a group of learners (Abdulbaki, Suhaimi, Alsaqqaf & Jawad, 2018). Sometimes this method is regarded as the “telling method” (Abdulbaki et al., 2018, p. 285). The teacher’s talk encompasses both lecturing and discussions with learners. Lectures are sometimes accompanied by visual aids, such as slideshows and documents. Some teachers use whiteboards or chalk boards to emphasise important points during their lectures. Nonetheless, a lecture does not require any of the above-mentioned characteristics to qualify as a lecture, it is classified as a lecture if an authoritative figure stands at the front of a room and delivers a speech to a crowd of learners.

One of the oldest methods of teaching geography is the lecture method (Omoro & Nato, 2014). Since GIS is embedded in geography, it follows, then, that most geography teachers use the lecture method when they teach GIS. Mukwa and Otieno (2006) state that teachers use verbal messages to create and stimulate the learners to get involved during the teaching and learning process. Teachers are regarded as the source of information, with learners' primary responsibility being to listen and take notes (Malusu & Wachira, 2008). “The lecture method gives the teacher maximum control over learners”, since it is a teacher-centred approach. The teacher controls what, when and how learners learn in the class (Killen, 2012, p. 126).

The lecture method is divided into two types: formal lectures and informal lectures. Communication in a formal lecture is one-way, whereas communication in an informal lecture is a two-way process between the teacher and learners. The informal lecture is more applicable to GIS teaching because it allows the teacher to receive feedback from the learners. However, teachers have been known to use the formal lecture method when introducing new concepts and factual information, and when teaching large classes (Gitau, 2008). According to Thungu et al., (2008), cited in Omoro and Nato, (2014), the formal method restricts learners' participation during the lesson and does not promote or develop learners' reasoning abilities because their role in the lesson is to listen and take notes. Alcorn (2010) defends the use of lectures on the grounds that it is appropriate for situations where a teacher presents important content that is not easily available, supplements information in the textbook, or summarises essential points after a unit of study.

In this teaching method, the teacher’s personality is important. The teacher’s voice should be audible, and pronunciation of terms should be clear. The teacher can augment this method by using appropriate gestures (Kaur, 2011). It is reported that before a teacher chooses to use this method, he/she has to consider the following (Omoro & Nato, 2014):

- In order to improve teaching effectiveness, the teacher should combine the lecture method with audio materials;
- The language used by the teacher must be understandable and followable by the learners;
- The teacher should plan and organize the main points of the lecture in a systematic and logical manner;
- The personality of the teacher should be competent, friendly, and interesting;
- Teachers must consider their learners and devise strategies to ensure that they follow and comprehend the lecture, such as providing handouts.

The lecture method has advantages and disadvantages. Kellough and Kellough (1996, p. 429) state that the purposes of the lecture method/teacher talk, whether the lecture is formal or informal, is to accomplish the following purposes:

- Introduce a unit of study;
- Present a problem;
- Discuss the progress of a unit of study;
- Explain an inquiry;
- Promote learner inquiry or critical thinking;
- Provide a transition from one unit of study to the next;
- Provide information otherwise unobtainable to learners;
- Share the teacher's experiences;
- Share the teachers' thinking; and
- Teach a thinking skill by modelling that skill. (Kellough & Kellough, 1996, p. 429)

Clark, Kirschner and Sweller (2012) advise that a lecture should attract learners' interest and attention. This can be accomplished in a variety of ways, including the teacher beginning the lesson with a challenging question, stating a problem, or providing a confusing fact. The confusion created will draw the learners' attention to the lesson.

Advantages of the lecture method

The lecture method has several advantages that have contributed to its long-standing status as the standard approach to teaching (Paris & Winn, 2014, p. 25). These advantages include the following:

- **Teacher control**: The lecture is delivered by one authoritative figure – a teacher, professor, or instructor. This means that the person can control the direction of the lesson and the tone of the classroom. Only the person in front is able to shape the course, so lectures remain highly consistent in relation to delivery of information.
- **New material:** Lectures are literally just long-winded explanations of information, deemed important by the teacher. Therefore, learners can absorb large quantities of new information.
- **No effort by learners:** The lecture method makes the learning process relatively easy for learners, as they only need to pay attention during the lecture and take notes as needed. The fact that learners are required to provide little input indicates that the method is the clearest, most straightforward, and uncomplicated way to expose learners to large amounts of information, but it does not develop learners' reasoning abilities (Omoro & Nato, 2014, p.222).

Disadvantages of the lecture method

Some of the disadvantages of the lecture method include the following (Gitau, 2008, cited by Omoro & Nato, 2014, p.222):

- **One-way:** Opponents of the lecture technique believe it is a one-way street. Because teachers dictate the information, learners have little to no opportunity to add their own personal opinion or comment on it.
- **Passive:** The lecture method is a wholly passive experience for learners.
- **Strong speaker expectation:** The lecture method can suffer from the audience's expectations; however, teachers are not all skilled public speakers. The lecture method can be used successfully to teach GIS, especially when the teacher introduces a new topic to the class. This method enables the teacher to introduce the new topic and explain new terms in great depth, for instance, when a teacher introduces the class to GIS for the first time.

ii) DISCUSSION AS A METHOD OF TEACHING

Discussion is defined by Gitau (2008), as cited in Omoro & Nato (2014, p. 223), as "the spoken contact between persons that consists of asking questions and delivering answers." The strategy entails active engagement from learners as well as feedback. Discussion as a teaching method is appropriate for teaching GIS, because it trains learners and helps them develop skills on how to utilise facts and information. Learners improve their capacity to convey ideas, make learning more realistic, and get a greater comprehension of the subjects being taught (Quist, 2005). Exposition-oriented discussion and inquiry-oriented discussion are the two types of discussion strategies (Ayoti & Patel, 1992). Before concluding in an expository discussion, the teacher presents objectives, discusses the learning activity, demonstrates it, and then encourages questions from learners (Awiti, 2010). The inquiry-oriented discussion is the second type of discussion. In this style, the teacher sets the goals and organises the conversation and the entire activity in an open-ended manner. According to Awiti (2010, cited in Omoro & Nato, 2014), an effective discussion between teacher and learners necessitates the teacher providing the necessary documents or directing the learners to obtain the information in appropriate groups, as well as the learners being given adequate time to research information on the topic.

Finally, the teacher's duty throughout a discussion is to guide. Learners are encouraged to share their opinions and actively participate in class (Ngaroga, 2008; Gall & Gillet, 2010; Abdulbaki et al., 2018). This method is excellent for teaching when the issue to be discussed needs a flow of information and ideas from the teacher to the learners, from the learners to the teacher, or between the learners.

iii) QUESTIONING AS A METHOD OF TEACHING

In this method, the teacher poses questions, to which the learners respond (Criticos, Long, Moletsane & Mthiyane, 2002; Omoro & Nato, 2014). The questioning method is one of the oldest and most widely used teaching methods (Kyalo, Osano, Maundu, & Kipkemboi, 2006; Mullen, 2003; Sewe, 2006). However, it is said to be the most abused teaching method (Alebiosu, 2002; Ngaroga, 2008). Teachers who do not prepare well for their lessons, for example, frequently use this method to pass the time. Teachers frequently bombard learners with questions, leaving little time for them to think and respond. As a result, the teacher will be answering his or her own questions (Howe & Abedin, 2013).

The effectiveness of this method must be tailored to train the learners to think independently (Ramsey et al., 2010). Questioning can be done for various reasons. These reasons include the following:

- “to interest, engage and challenge learners;
- to check on prior knowledge and understanding;
- to stimulate recall, mobilizing existing knowledge and experience in order to create new understanding and meaning;

- to focus learners' thinking on key concepts and issues;
- to help learners to extend their thinking from the concrete and factual to the analytical and evaluative;
- to lead learners through a planned sequence which progressively establishes key understandings;
- to promote reasoning, problem solving, evaluation and the formulation of hypotheses;
- to promote learners' thinking about the way they have learned"

(Lombardi, 2019, p. 20)

The questions that the teacher asks the class are of various types, including factual questions, which simply necessitate the memory of facts and mental problems, which require effective thinking (Ramsey, et al., 2010; Shanmugavelu et al., 2020). The question method can also be used to check whether the learners have understood the content taught and whether the learners have interacted well with the material. The subject of geography should assist learners in stating, interpreting, analyzing, and applying geographical principles and methods to deal with environmental issues (KIE 2008; Omoro & Nato, 2014). As a result, geography teachers should use thought questioning in their instruction to make sure that learners accomplish the curriculum objectives. The type of question asked will also be determined by the reason for asking it (Lombardi, 2019). Some questions can be 'open' and some can be 'closed' (Lombardi, 2019). Closed questions usually require a single answer and are used to check the understanding of the concept being taught. The teacher can use closed questions to recap understanding of the previous topic. For example, if the teacher wants to check recall, then he/she asks a closed question, such as "What is the grid reference for Great Malvern?" (Lombardi, 2019, p. 20). Open questions, on the other hand, necessitate and aid in the advancement of higher order thinking skills in learners (Omoro & Nato, 2014; Lombardi, 2019). Open-ended questions allow learners to respond in a variety of ways. It is useful to aske open questions during a class discussion to probe deep learning and higher order thinking in learners.

In addition, Omoro and Nato (2014) stated that the teacher should follow the following steps to ensure the questioning method is effective:

1. Clearly state thequestion;
2. Pause, to give learners time to consider the answer to the question;
3. Call out a learner's name;
4. Listen to the response; and

5. Comment on the response.

Various benefits can be realised from using the questioning method. The teachers can use it strategically, thereby keeping learners on task and encouraging them to engage in meaningful learning. These advantages can be achieved with proper questioning strategies. The teacher should develop an effective questioning style that ensures learner participation and understanding. Teachers must also develop clear communication and listening skills when using this teaching method. Du Toit, Louw and Jacobs (2016) argue that asking proper questions at the right time can stimulate and unlock the prior knowledge of the learners in the class.

Therefore, questioning, which is the cornerstone of inquiry, can be used to create a supportive classroom environment in which learners' inputs are valued (Du Toit et al., 2016). Good questioning skills include redirecting the question, prompting, pausing (waiting for a time after asking a question), handling incorrect responses and seeking clarification (Du Toit et al., 2016, Killen, 2012).

Effective questioning

Effective teachers, according to research, ask more open-ended questions than less effective teachers. Of course, the number of open and closed questions used in a class varies on what is being taught and what the teacher aims to accomplish. Teachers who do not ask open-ended questions in class, on the other hand, may be providing learners with insufficient cognitive difficulties (Killen, 2012; Du Toit et al., 2016; Lombardi, 2019). When learners are able to actively participate in the learning process by developing responses, questioning is effective.

Scholars (Muijs & Reynolds, 2011 cited by Lombardi, 2019) have suggested that effective questioning lessons should include the following features:

- Questions are carefully planned and closely related to the lesson objectives.
- The learning of fundamental skills is aided by frequent questions following the presentation of new content in small steps. Each stage should be followed by guided practice, which allows learners to consolidate their learning while also allowing teachers to measure comprehension.
- Closed questions are used to assess factual comprehension and recall.
- Unanswered questions predominate.
- Learners are encouraged to provide feedback to one another.

- The cognitive level is raised as the questions continue in a question sequence. This guarantees that learners are steered to solutions that demand increasingly higher order thinking skills while simultaneously being supported by questions that require less advanced thinking skills along the way.

(Lombardi, 2019, p. 35).

The redirection of the question is usually done after a first learner's response. In this case, the teacher nods, and points to the next learner to indicate that he or she should add to the first response (Shanmugavelu et al., 2020). Pausing is very important when questioning learners. This encourages learners to think and formulate an answer. In addition, skills for handling responses by the learners are important, as teachers should guard against discouraging communication when learners give incorrect answers (Killen, 2012; Du Toit et al., 2016).

Problems of questioning as a teaching method

Although questioning is the most commonly used teaching method, it has some drawbacks. This section identifies and suggests ways to avoid some of the most common pitfalls of questioning.

1. Not being clear about why you are asking the question: The teacher has to reflect on the kind of lesson he/she is planning and think about the questions he/she is going to ask to the learners. The teacher has to sequence the questions properly so that they can develop higher cognitive thinking in the learners. To promote that, the teacher needs to use open questions.
2. Asking too many closed questions that require only a brief response.
3. Asking too many questions at the same time.
4. Asking difficult questions without preparing for them.
5. Inquiring about trivial matters.

iv) EXPLANATION AS A METHOD OF TEACHING

The statement by Calefee and Drum (1986, pp. 1-2), "Good teaching is good explanation", highlights the centrality of the explanation of concepts in teaching. The explanation teaching method remains the cornerstone of teaching in both the teacher-centred and learner-centred approaches (Criticos et al., 2002; Odora, 2017). Even in an entirely learner-centred lesson, teachers need to explain concepts in an orderly and clear manner in order for learners to understand the concepts being taught. Explanation is not merely didactic lecturing, reading from textbooks or aimless chatter, instead, it should be structured teacher-talk aimed at clarifying concepts so that learners can understand and change their thinking (Criticos et al., 2002). Therefore, the main purpose of explanation in education is to unlock learner understanding of the concepts being taught, and to promote learners' logical thinking (Odora, 2014; Odora, 2017).

However, there are problems with the ways that teachers use explanation. Criticos et al. (2002) cite the following problems:

- Overusing explanations;
- Using explanations badly;
- Using explanations inappropriately; and
- Failing to take responsibility for explanations that do not work and, instead, blaming learners for not understanding.

Characteristics of a good explanation

An effective explanation should be logical, should provide learners with ideas, and must be a well-connected, step-by-step explanation. Good teachers who use the explanation teaching method mix the explanation method with other methods to maximise learning. For example, a teacher can, while explaining concepts, use GIS maps to engage the learners' senses of sight and hearing to help them understand. In addition, a good explanation involves repetition of key points to enhance understanding. Repeating key points in different ways ensures that learners know what is important and increases that chance that learners understand. Finally, a good explanation should be brief and to the point, as this will help the learners understand the critical and foundational knowledge required.

Types of explanations

There are three kinds of explanations: interpretive explanations, descriptive explanations, and explanations that provide reasons (Criticos et al., 2002; Odora, 2017). Each type serves a particular function in teaching. Thus, an interpretative explanation serves the purpose of explaining the essence of a concept and seeks to clarify it. Descriptive explanation serves the purpose of explaining the "how is" and "how does" aspects. This type of explanation can describe a process during the explanation. Reason-giving explanations provide reasons or causes. They explain why certain things happen. Different types of explanations achieve different goals and are structured differently as a result.

2.6.1.2 LEARNER-CENTRED PEDAGOGY

Learner-centred pedagogy, also known as learner-centred pedagogy, refers to instructional methods that shift the emphasis away from the teacher and toward the learners. Throughout the twentieth century, several psychological developments influenced the development of this approach, including perceptual psychology, constructivism, and disposition (Henson, 2003). Learner-centred pedagogy is also said to be founded on social constructivism theory, because social constructivism acknowledges the social nature of the learning environment as a collaborative environment between teachers and learners in class (Murphy, 1997; Dougiamas, 1998). Learners in a social constructivist classroom are encouraged to take an active role in constructing their own knowledge rather than simply memorizing and reciting the answers (Roesler, 2002; Singhal, 2017; Ncube, 2018). Learner-centred education can thus be defined as a method that includes terms like active learning, exploration, self-responsibility, prior knowledge and abilities and knowledge construction rather than passive learner participation (McCombs & Whisler, 1997; Edmund & Stephens, 2000; Langu & Lekule, 2017).

Learner-centred pedagogy aims to foster learner independence by putting learners in charge of their own learning. It entails learner-centred instruction that focuses on skills and practices that promote lifelong learning and problem-solving independence (Jones, 2007). Learner-centred learning is also defined by concepts such as collaborative learning (Moore & Zyomont 2003), flexible learning (Taylor, 2000), experiential learning (Burnard, 1999a), learner-centred learning (Jones, 2007), and self-directed learning. This pedagogical approach is based on learning theories that advocate for learners to participate actively in the learning process. Learners should create knowledge by combining prior knowledge and new experiences. Learners who have greater prior knowledge tend to have greater success in colleges than those who do not have it (Kurlaender & Howell, 2012). From this understanding, therefore, it is the duty of teachers to facilitate the process by tapping into the prior knowledge learners have already and connecting it to the new knowledge the learners should learn. The extraction and utilization of learners' previous knowledge can be accomplished in different ways. The teacher may choose to have a small class discussion, or she/he can give a written activity where the learners can write down what they know about the topic at hand. This can aid in determining what the learners know and don't know and dispel any misconceptions they may have about the topic's content. Following that, teachers can assist learners by creating enabling learning environments that allow them to connect their prior knowledge to the new knowledge. Advocates of learner-centred pedagogy generally take a constructivist approach, asserting that learners build their understanding by their actions and experiences in the real world (Mascolo, 2009). Furthermore, learner-centred pedagogy is often accompanied by a problem-solving strategy, in which problems are chosen to pique learners' interest and to focus on the needs of learners (Jayalakshmi, 2015). Figure 2.4 summarizes some of the learner-centred pedagogical approaches that teachers can use when teaching GIS.

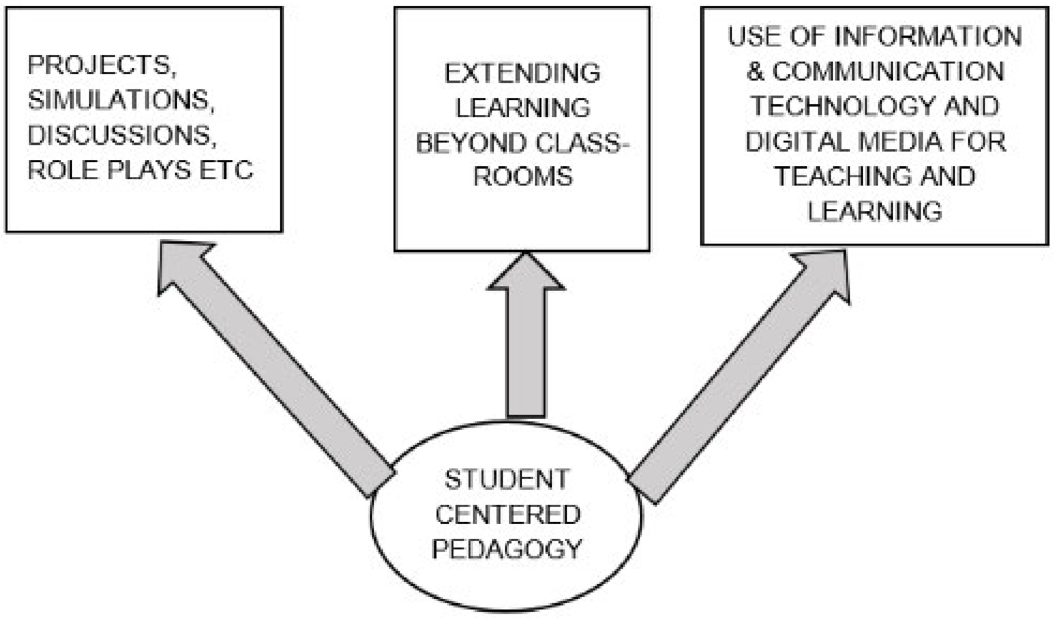


Figure 2.4: Learner-centred pedagogy

Source: Singhal (2017, p. 5128)

Learner-centred pedagogy can be traced back to constructivist developmental theory (Piaget, 1948; Kolb, 1984; DeVries & Kohlberg, 1997; Fosnot & Perry, 2005). Jean Piaget, Jerome Bruner, Lev Vygotsky, and John Dewey are key figures in the constructivist paradigm. Piaget claims that children think and reason differently than adults, which led him to believe that children are active learners who do not require adult motivation to learn. As they progress through the stages of cognitive development, children interpret knowledge differently than adults. Piaget states that two key components that lead to the construction of new knowledge in an individual are accommodation and assimilation. Assimilation is the process by which a person integrates new and old experiences (Bada, 2015). However, the new knowledge will, at first, cause a cognitive disequilibrium cognitive dissonance (confusion or disagreement with known information) (Ormrod, 2008). Once this has happened, the learner will adjust in order to accommodate the new knowledge (Piaget, 1948). This cognitive disagreement allows teachers to see what is going on in learners' heads and encourages teachers to provide learners with learning opportunities that will assist them in reconstructing their beliefs in a way that accommodates new information and forming concrete changes.

Learning, according to Bruner (1996), is an active process in which learners develop new ideas or concepts based on their present and former knowledge. He emphasizes the fact that children are constructivist and participatory learners who actively participate in the learning process. As a result, the teacher's part is to assist and encourage learners to discover the main principles on their own.

Other key proponents of the constructivist theory include Lev Vygotsky and John Dewey. These scholars postulate that learning is influenced by social development and takes place within children's social development and culture. Dewey contends that education is a social process, and thus learning should engage and broaden learners' experiences. It follows, then, that learners can learn geography and GIS if they socialise among themselves as they learn. The teacher can help learners learn by dividing them into groups, where they can complete a task together as a group.

i) DISCOVERY LEARNING AS A TEACHING METHOD

This type of pedagogy involves searching for information in places of learning, such as the library, and through fieldwork. In this regard, learners visit the library to search for relevant literature and discover ways to solve authentic problems (Clark, Kirschner & Sweller, 2012) The introduction of the internet means that learners can discover information much easier. Lyu and Wang (2018) note that web searches are often much more effective than traditional library searching. Learner activities, including library searches, lead to discovery learning, which is a highly self-directed and constructivist type of learning (Lyu & Wang, (2018). Furthermore, Lyu and Wang (2018) further state that the constructivist learning system necessitates a diversity of perspectives, allowing learners to gain a diverse set of possibilities from which to build their own expertise. As a result, the teacher's primary role is to provide pupils with coaching or scaffolding to aid in their exploration.

Learning by doing is a kind of hands-on experience. It is a hands-on learning method in which pupils learn by doing. Practical tasks are pivotal in this approach and, thus learners put their skills to the test and put their knowledge to the test in a very practical way. Access to the internet means that learners can do the simulations using online programs, record their knowledge, questions and critiques, and get feedback from a variety of people. Learning by doing as pedagogy is, as noted by Sivakumar, (2018). According to Basheer et al., (2017), learning is one of the most efficient methods for assisting learners in developing their own knowledge.

ii) DEMONSTRATION AS A TEACHING METHOD

Demonstration is one of the methods of teaching often used in geography and GIS teaching. According to the CAPS document, learning GIS in high school should allow the learner to acquire necessary skills that will serve as a foundation for technological and industrial development (DoE, 2004). In most cases of GIS teaching, learners acquire skills through demonstration. Thungu et al., (2008) assert that learning by observation, and then doing, and executing drills and practical exercises, are necessary for learners to understand concepts in geography, such as GIS. Topics in geography, such as measuring bearing, buffering and digitisation in GIS, can be taught effectively through demonstrations. Mukwa and Otieno (2006), cited by Omoro and Nato, 2014, p. 224) "observed that the emphasis in demonstration is learning by observing and it should often be followed by doing". The demonstration method combines telling, showing, and doing. The saying, "when I do, I understand", supports this description because it teaches learners to be effective observers and encourages them to think critically and able to form concepts and generalize them (Malusu & Wachira, 2008). However, in order for this method to be effective, it must be thoroughly planned and practiced by the teacher. This preparation is critical since the method exposes the teacher to the learners' own assessments, and the demonstration's effectiveness demonstrates the teacher's competency (Omoro & Nato, 2014; Basheer, et al., 2017; Sivakumar, 2018).

iii) FIELDWORK/FIELD STUDY AS A TEACHING METHOD

Fieldwork is one of the teaching methods that can be used in high schools to teach GIS. Fieldwork, according to Hurry (1991), is any educational activity that takes place outside of the classroom. This educational activity may take place in the school grounds, a local park or in anywhere where practical outside activities are possible. Hurry, Toombs & Roberts (2015 add that the duration of the fieldwork can range from less than one school period to several days, depending on whether the activity is part of a school period or part of an extended fieldwork program. Hurry, Toombs & Roberts (2015) state that the terms fieldwork and field excursions are used synonymously to refer to learning through direct experience of "the real thing" in the field. The field excursion, according to Hurry, Toombs and Roberts, (2015) cannot be taken as an entertainment.

Fieldwork is often defined as any curricular component that requires learners to leave the classroom and participate in teaching and learning activities by observing events first hand (Boyle et al., 2007; David et al., 2019).It is advanced that learning in the “real world” is thought-provoking and makes learners curious about what they will learn, thereby contributing to the qualities that run through geography’s identity: commitment to exploration and enquiry, and concern with discovering the world (David et al., 2019, p. 1438).

PURPOSE OF FIELDWORK

Fieldwork makes it easier to achieve a variety of goals. These include attitudinal and aesthetic goals, as well as knowledge and skill goals (Han & Foskett, 2007). Fieldwork with attitudinal and aesthetic goals has specific, related goals. These goals are to arouse learners' curiosity, to develop positive attitudes toward learning, inspire learners to recognize difficulties and ask questions, enhance learners' awareness and understanding of the changing landscape, provide the thrill of discovery, enjoy active geography study, and develop a deeper interest in the subject (Boyle et al., 2007; Hovorka & Wolf, 2009).

Furthermore, fieldwork that focuses on knowledge activities, allows learners to watch, think, and learn about the work covered in the classroom; it highlights the relationship between physical features and human activity; and it improves awareness of problems created by human effect on the environment (Kent, 2007). Fieldwork with a skills-objective focuses on developing geographical modes of inquiry, orienting learners in the field, connecting real-world characteristics to map symbols, and encouraging data gathering, record keeping, and analysis skills.

Types of fieldwork

There are different types of fieldwork. The purpose of fieldwork determines the categories of fieldwork (Hurry et al., 2015). Fieldwork can be grouped into three kinds, namely, field demonstrations, field studies and field research.

- **Field demonstrations:** In this type of fieldwork, the teacher explains the environment to the learners. Field demonstrations are used to supplement classroom learning. An interpretative trail is one in which a teacher guides pupil along a set path while explaining the environment, is an example of a field demonstration. In this type of fieldwork, the movement of learners participating in the fieldwork is restricted. Learners observe, listen and take notes; hence, the learners are passive, as they are only listening and taking notes.

- **Field studies:** Field studies engage learners more actively. The teacher's duty is to guide the learners by means of worksheets or verbal instructions (Hurry et al., 2015). Although the activities are controlled, there is room for learners to express themselves. Field studies can be classified into four types: descriptive studies, hypothesis testing, problem-solving studies, and comparative studies.
    - **Hypothesis testing:** The emphasis in this type of fieldwork is on observation, data collection, and analysis. The teacher presents the hypothesis (theory) to the learners, who then devise their own research methods (Hurry et al., 2015).
    - **Problem-solving:** A problem is presented to the learners, and they are asked to come up with viable solutions to solve it. The focus is on data collection, recording, and analysis, with a focus on the topic under research. In this case, the learners are given the problem and have to decide what data needs to be gathered in order to solve the problem. Thus, for a problem such as rural-urban migration, learners will be tasked with identifying the causes of this phenomenon and making suggestions for how it can be addressed (Preston, 2016).

BENEFITS OF FIELDWORK

Fieldwork teaching approaches offer a variety of benefits to learners. One of the benefits is that it makes geography and theories come to life for learners (Preston, 2016; Claiborne, et al., 2020). Doing so will improve learner knowledge and understanding of geography. It also helps in developing learner skills, particularly skills in data collection, analysis and map work. Fieldwork also teaches learners observational and investigative skills, computer and technology skills, as well as communication and mathematics skills. Above all, the learner will appreciate the environment and will have the opportunity to experience and enjoy a variety of environments and landscapes.

Fieldwork may provide the motivation that many geography learners lack. When the learners go out in the field to learn about geography, they may be compelled to think geographically. As a result, they will have acquired a set of skills and techniques that will serve them well in the future (David et al., 2019). Furthermore, fieldwork assists learners to understand other peoples and their cultures (Anđelković, et al., 2017). The learners broaden their perspectives on social, political, and environmental issues, take responsibility for their learning, gain confidence, and develop other skills such as leadership and teamwork (David et al., 2019). As a result, geographers regard fieldwork as an essential tool for understanding our world through direct experience and gathering basic data about it, which improves geography education.

A well-designed fieldwork experience should achieve a variety of objectives, including the development of observation skills. Fieldwork assists learners in focusing their observations on a specific phenomenon in this way. The observation may be conducted without the presence of a teacher and teaches learners to observe scientifically and critically on the topic (Hurry,1991; Morphet & Peck,1994; Winter, 2000).

Successful fieldwork must also facilitate experiential learning. This implies that the geography teacher should begin in the field before moving to the classroom. A teacher teaching river systems and processes, for example, should first take learners to a river environment so they can see what a river looks like, and then follow up with classroom lessons. According to Arjun (1990, p. 25), "this is known as the interpretative approach in which beliefs, feelings, attitudes, and values are explored." Fieldwork also encourages learners to take charge of their own education. According to David et al., (2019), field study makes learners more responsible for their own learning than traditional classroom instruction. As a result, fieldwork allows learners to do their own research and ask their own questions about the data they've collected.

Finally, fieldwork develops learners' analytical skills. Learners have to analyse the information after they have collected the data, in order for them to arrive at a conclusion. For instance, in a geomorphology exercise, learners can gather samples of rocks, and analyse and classify them into different categories of rocks, such as igneous, sedimentary and metamorphic rocks.

iv) PROJECT AS A TEACHING METHOD

A project method, according to Omoro and Nato (2014), is a unit of activity that learners engage in a natural and lifelike manner while maintaining a sense of purpose in order to achieve a stated, pleasurable, and seemingly attainable goal. Projects are an important teaching method; projects are designed and carried out by learners under the supervision of a teacher (Claiborne, et al., 2020). Learners draw on their own background experience to establish their project goals. The teacher encourages learners to work through the study activities in order to attain those goals. A project, according to Malusu and Wachira (2008), is a group or individual investigation into a real-life, difficult situation in its natural surroundings. the goal of achieving a positive and concrete outcome. For example, learners may be taken to a location near the source of the problem in order to learn more about it. Thus, the topic chosen for study in the project method should be a real problem that affects the learners in the environment where they live.

This teaching method emphasises the involvement of the teacher as a guide (Omoro & Nato, 2014), and it falls under the learner-centred pedagogical approach. According to West (2007, cited by Omoro & Nato, 2014, p. 225), a proper project method, when implemented by the teacher, permits learners to begin and pursue information, learn and work at their own pace, cultivate a sense of curiosity, acquire knowledge, and interact with real-world problems, challenges, and opportunities. For example, the 9th and 10th grade learners in Istanbul, Turkey used the Project method to learn about GIS in geography. At the end of the project, the learners were able to create a map depicting the locations in the district where disabled pedestrians can travel on sidewalks on their own. This project demonstrated the value of GIS as a learning and teaching tool in schools (Demirci, 2011).

The benefits of the project method align with one of the goals of secondary school GIS instruction, which stipulates that pupils should exhibit the adoption of positive attitudes, values, and self-reliance abilities (DoE, 2003).

2.7 GIS TEACHING IN SECONDARY SCHOOLS

This section describes the experiences of countries that have incorporated GIS in their geography curricula. In recent years, GIS technologies have advanced rapidly and gained global significance (DeMers, 2016; Lehner, Jekel, & Vogler, 2017; Musakwa, 2017; Yuan, 2017). Over the years, the incorporation of GIS in many secondary schools has increased and improved educational results in geography, as well as enhanced educational plans around the world (Çepn, 2013; Demirci, & Milson, 2015; Riihelä & Mäki, 2015; Millsaps, 2016; Harte, 2017; Jadallah et al., 2017; Metoyer, & Bednarz, 2017; Millsaps & Harrington, 2017; Mitchell, Roy, Fritch & Wood, 2018; Hong & Melville, 2018).

GIS education has been adopted and taught in many developing countries throughout Asia (e.g., China, Malaysia, and India) and Africa (e.g., Nigeria, Uganda, Rwanda, and South Africa) (Mzuza & van der Westhuizen 2019). Despite the increased emphasis on educational GIS, many teachers worldwide struggle to find appropriate methods of presenting GIS practical lessons or applying GIS in the classrooms due to a variety of challenges, including a lack of resources (Baker, Palmer & Kerski, 2009; Ates, 2013). These challenges are not only unique in Africa, but globally. Studies done in Europe, UK and USA revealed that GIS education face a multitude of challenges (Çepn, 2013; Singh & Singh, 2013; Skelton, 2014; Bearman, Munday, & McAvoy, 2015; Musakwa, 2017).

2.7.1 GIS TEACHING IN JAPAN AND PEDAGOGICAL APPROACHES

GIS was included in Japanese Education curriculum in 1995 (Gold, Haigh & Jenkins 1990; Winter, 2000). It was introduced in 1995, and yet worldwide GIS is not yet widely distributed (Bevainis, 2008). In addition, it is purported that only motivated teachers have been using GIS for their elementary classes (Bevainis, 2008).

The pedagogical approaches used by teachers to teach GIS in high schools in Japan is fieldwork and project engagement. Fieldwork is one of the most recommended teaching approaches for both geography and GIS. It is a learner-centred approach in which learners are given the chance to discover knowledge on their own, through research. The content and the steps followed in this pedagogical approach in Japan are explained below. To begin, the teacher shows the learners a map that depicts the appearance of strangers as an immediate threat (Ida & Yuda, 2012). The learners were then asked to guess where on the map they saw the locational distribution and what form of distribution it was. Learners were taught to anticipate the characteristics of sites where strangers were likely to appear in this scenario. The learners were then told to go out into the field and conduct research to put their hypotheses to the test. After collecting data in groups, learners were asked to plot the locations of streetlights and bushes on a computer map as their findings. Later, learners were instructed to use the GIS overlay function to examine the relationship between locations where suspicious people appeared and the data they had gathered. The learners should be able to superimpose various data layers on the map. Through this project, learners could provide GIS knowledge and skills to a local school while also conducting an experimental application of overlays in GIS. All methods, techniques, and strategies used to teach GIS in Japan explicitly adhere to the learner-centred pedagogical approach.

This pedagogical approach helps learners to acquire hands-on learning, from the start of the research project, to its end. The approach promotes active learning and the sharing of ideas, and it resonates well with pedagogical approaches to teaching and learning that are considered appropriate for the 21st century (Frache, et al., 2019).

2.7.1.1 CELLULAR PHONE GIS

Cellular phone GIS is another technique used in Japan. The GIS application for cellular phones is a Java-based application for a Japanese 3G cellular phone. When the map or data is required, the application connects to the database server where it is stored and retrieves it. In this case, users can plot data on the mobile phone's map (Ida & Yuda, 2012). This technique requires learners to go out and collect data during fieldwork using their cell phones. After collecting the data, the data is uploaded on a desktop computer. Cell phone GIS systems rely on the GIS application embedded in mobile phones, an internet-browser-based viewer for PCs, and the data server that links them (Welsh & France, 2012). The cellular phone GIS application can be used to input and edit data while outside. In this case, the data can be accessed via the internet on both cellular phones and personal computers (see Figure 2.5).

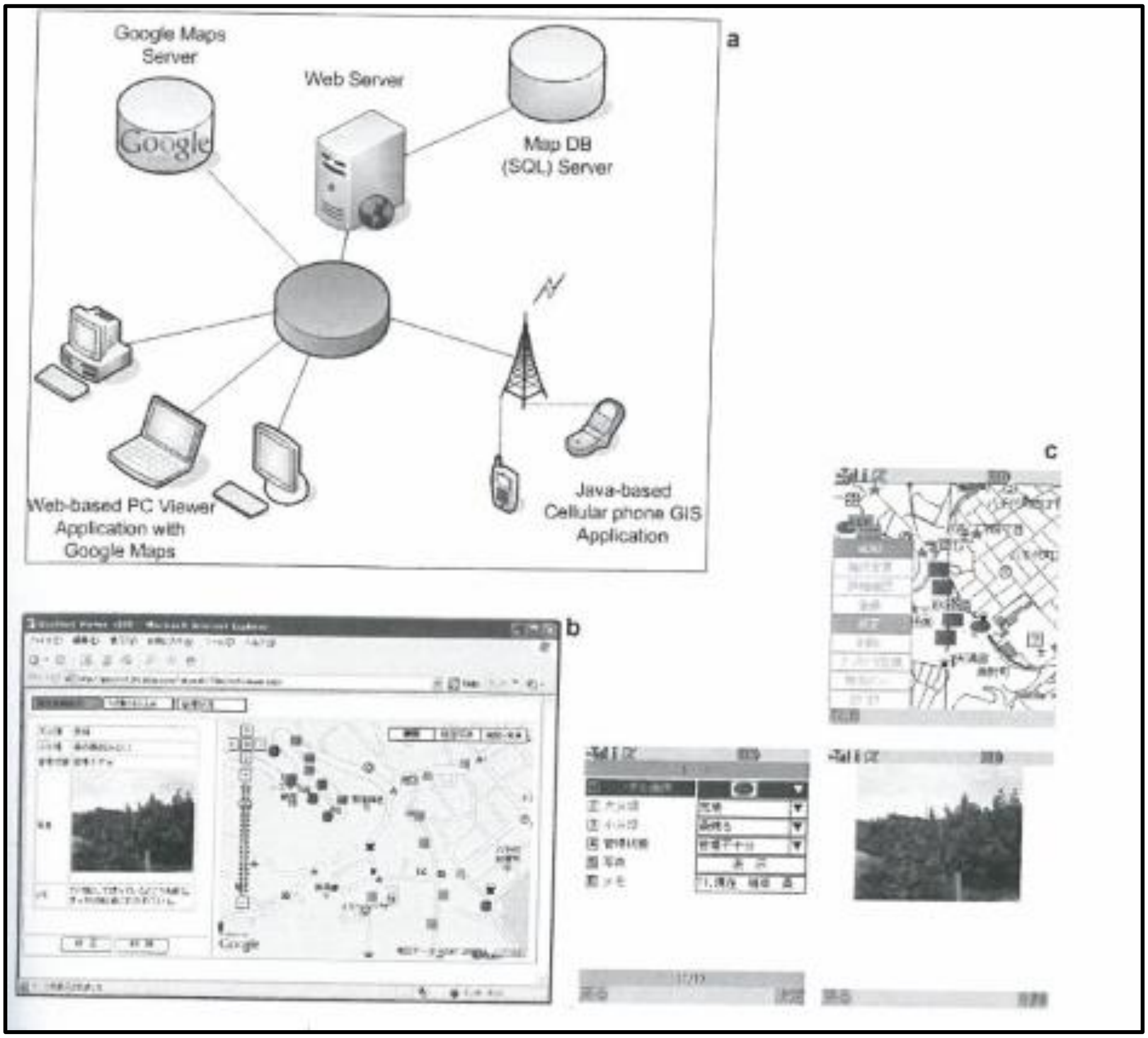


Figure 2.5: Use of cell phone to teach GIS

Source: Ida and Yuda (2012)

2.7.1.2 BENEFITS OF CELLULAR PHONE GIS

One of the primary advantages of cellular phone GIS is that it encourages active learner participation in class. It is suggested that the operation of the mobile phone does not need any explanation to learners, since the learners are used to using cellular phones (Yuda & Itoh, 2006; Ida & Yuda, 2012). Data can be uploaded during fieldwork in the field; hence, learners can complete the project on time. Because cellular phones are widely used, accepted, and well known among learners, cell phone GIS applications are likely to be accepted by secondary school learners. Furthermore, the fact that only a cell phone, an internet connection, and a web browser are essential suggests that cell phone GIS applications can be introduced even in poor high schools in developing countries such as South Africa. Because the majority of learners in South Africa own smart phones, these approaches used in Japan can be very useful in the South African context.

2.7.2 TEACHING IN ALBANIA

Another country that has introduced GIS in its curriculum is Albania. I choose this country because it is located in Europe and is classified as relatively developed country. GIS is taught in Albanian secondary education from Grade 9 to 12. The course is built around data and software that can be accessed both online and offline. The data includes both Albanian and global themes, vegetation classification, climate, soil types, and urban landscapes, and the software used includes the Environmental Systems Research Institute's (ESRI) ArcGIS online map services and ArcGIS Explorer, as well as Google Earth (Papajorgji & Zwick, 2013). Various pedagogical principles are used in Albanian secondary schools.

SPECIFIC PEDAGOGICAL OBJECTIVES

The specific pedagogical objectives aim to achieve the following:

- Teaching with GIS rather than about GIS;
- Integrating across many media forms;
- Integrating concepts across disciplines;
- Connecting learners’ personal experiences and practices to the larger world;
- Creating a mixed-age classroom, rather than an age-group cohort classroom;

- Keeping the balance between the role of learners as consumers of knowledge, versus that of producers of knowledge; and
- Creating a networked rather than a hierarchical structure in the classroom, with multiple teachers working as peers with the learners and in concert with one another (Papajorgji & Zwick, 2013, p. 1).

2.7.2.1 PEDAGOGICAL APPROACHES USED BY GEOGRAPHY TEACHERS IN ALBANIA

The pedagogical approach used in Albanian schools to teach GIS is based on the European Pedagogical ICT license (EPICT). It focuses on the use of ICT tools in the classroom using a constructivist perspective. The concepts that are taught are explained theoretically in the first steps of the implementation of the approach. As a first step, teachers show learners how to use key functions (query, buffering, overlay, analysis of topological relationships, spatial interpolation, creation of terrain three-dimensional models, localization, model and scenario construction, information representation) before asking them to implement (Adomi & Kpangban, 2010). Teachers are also supplied with GIS software, lesson plans and other requirements to use when teaching GIS. Teachers are also provided with assignments which they give to their learners to do in class. The assignments given to the learners are usually based on what learners are familiar with in their daily lives. The digital literacy approach is an approach that seeks to make every learner in the class capable of efficiently communicating and expressing their thoughts through digital media (Chan, et al., 2017). In this approach learners are taught how to represent their ideas and to think critical using digital media than just being taught information and communication technology skills (Chan, et al., 2017). In this case, learners will be taught how to use social media platforms such as Facebook, Twitter, and YouTube in this example (Ibrahim, Shariman, & Woods, 2013). This will encourage deep learning and allow learners to become critical thinkers (Houghton, Steel & Henty, 2004).

2.7.3 GIS TEACHING IN THE UNITED STATES

I chose the United States because it is advanced in its use of GIS in such institutions such as the military and it was introduced in high school education in 1996 (Manic et al., 2013). The United States was included in this study because it is one of the first countries to implement GIS in the high school curriculum. The GIS curriculum was introduced in secondary education in the 1990s and has since diffused slowly in K-12 classrooms (Bednarz & Ludwig, 1998). According to Demirci

(2009), less than 5% of high school geography teachers in the United States used GIS in 2003, while Kerski (2003) reports that 54.9 percent of schools that own GIS software do not use GIS for teaching. Bevainis (2008) claims that the slow diffusion of GIS in schools did not result solely from teachers' lack of skills, or because of GIS software, but emanated from other factors, such as negative attitudes towards GIS by geography teachers.

The United States GIS curriculum has various aims, including the need to investigate appropriate roles for GIS software and concepts such as analytic map skills, geography education based on exploring real world issues such as earthquakes, analysing demographic data, urban ghetto morphology and application of GIS in the secondary school curriculum, and to promote GIS within the secondary school curriculum (Goodchild & Palladino, 1995). Although including GIS is not compulsory, the K-12 statement suggests that it is included (Kerski, 2001). The pedagogical approaches used to teach GIS are not clearly stated. However, the curriculum seems to suggest learner-centred pedagogy, whereby learners are supposed to investigate and solve problems that affect the environment. Learners, for example, learn about and examine the hydrologic system, and they evaluate field data using GIS abilities. The teachers plan field trips and discussions with local experts who utilize GIS in their work. Learners enroll in a 'Principles of GIS' course in the second Geospatial Technology Pathway (GTP) program, which covers the application of trigonometry and statistics, as well as applied space science. Learners focus on GIS application in their final year of the GTP program and complete an internship with a local government or industry partner.

2.7.4 TEACHING GIS IN TURKEY

Turkey as a country is well known in trying to advance GIS teaching in high schools (Demirci, 2015). GIS was introduced in secondary school education in Turkey in the 2000s and it is taught in geography in Grades 9-12 (Demirci, 2012). GIS integration began in earnest in 2005. GIS was discussed at a very basic level in some textbooks prior to 2005 (Demirci & Karaburun, 2009).

GIS-based exercises and projects are used in schools in Turkey. Mapping Our World (Malone, Palmer & Voigt, 2003), a textbook, was a major source of inspiration for developing and testing GIS-based exercises in Turkish secondary schools. The GIS-based activity is developed as part of the geography curriculum, together with digital data and learner handouts, to teach learners concepts such as plate tectonics, earthquakes, and volcanoes. This arrangement seems to suggest that the pedagogical approach used to teach GIS in Turkey is teacher-centred, coupled with a textbook-based teaching method. Teachers acquire knowledge of GIS through workshop training. After the training, the teachers are given GIS materials to implement with the learners at schools. This arrangement seems to be similar to the South African approach.

However, before the publication of the book GIS for Teachers in 2008 (Tuna, 2008), GIS implementation in Turkey remained extremely limited (Demirci, 2012). The book addressed some of the challenges that teachers face, such as “understanding what GIS is and why it is used in various disciplines, comprehending the importance of GIS for education, having GIS software prepared in the Turkish language, comprehending how to use GIS software, and having educational materials, such as lesson plans, digital data, and GIS-based exercises, to be used in lessons” (Demirci & Karaburun, 2009, p.27). The book is a mix of theory and practice. The GIS exercises in the book are organized into three stages: “preparation, implementation, and assessment” (Demirci & Karaburun, 2009, p.27). Learners learn how to view data at various layers, answer questions by recognizing links between graphic and nongraphic data and execute basic spatial analysis operations. (Demirci, 2012). The document outlines each exercise's phases as well as the sorts of queries and analysis that were utilized to answer the questions. It is intended for learners with no prior GIS knowledge or skills. In addition to the GIS-based exercise approach that Turkey uses in schools, it also uses the project approach method to teach GIS. In this, learners are divided into groups and given a topic to research (Demirci, 2012).

This section provided information on the way different countries uses different pedagogical approaches to teach GIS. It was noted that the main pedagogical approaches used are project-based approaches and fieldwork. Both approaches are learner-centred, as they provide learners with the spatial instruments they need, such as GPS, to collect data in the field and upload it to computers running GIS software. The pedagogical approach used involves hands-on experience, and the methods allow learners to solve problems in live situations. The teaching of GIS theory is augmented by practical activities, where learners are asked to apply in practice what they learned in a classroom setting Learners can also produce their own knowledge by evaluating and designing maps that can be utilized to solve real-world environmental issues.

2.7.5 GIS TEACHING IN FINLAND

The other possible and promising pedagogical approach which can be used for teaching and learning about GIS is the Digital GIS Portifolio (Anunti, Vuopala & Rusanen, 2020). In this approach, a design-based research (DBR) is designed and given to the learners in high schools to complete. This pedagogical approach gives both the learners, and the teachers to engage and interact with the teaching material practically as they try to complete the project. The DBR portfolio comprises of six development cycles which included the following elements:" problem analysis, design process and design solutions" (Anunti et al., 2020, p. 263). A DBR approach is designed to be an educational process for pre-service teachers who have limited experience teaching GIS abilities, as well as a means of developing instructional resources to support learners' learning and growth of GIS abilities. The Bloom's taxonomy-based digital GIS portfolio approach includes increasingly difficult, inquiry-based tasks for learners. In 2019, the digital GIS portfolio was assessed as a pedagogical practice with learners enrolled in a Geomedia course at a local upper secondary school in Finland (Anunti et al., 2020). The approach turned out to be a very beneficial tool for GIS education. The portfolio boosted learner competency in using GIS, increased learner enthusiasm to learn about GIS, and increased learner perceptions of GIS importance. The approach promoted a teacher-centred approach to teaching GIS skills and was deemed essential. The findings of this study provide important information for Geography teachers as well as suggestions for improving teacher training in the subject (Anunti et al., 2020). Learners can collect geographic data in the field using GIS apps, as well as develop observation skills and promote their learning about GIS, using an inquiry-based task like Digital GIS Portifolio (Lee, 2020). To summarize, learners can use a digital GIS portfolio that includes alternative assignments at varying levels of difficulty to select projects that correspond to their level of competence and progress at their own pace from the easiest to the most challenging jobs. This teaching technique allows learners to work on their learning goals in a reasonably independent manner.

2.7.6 GIS TEACHING IN SECONDARY SCHOOLS IN AFRICA AND LIMITATIONS

This section discusses the current initiatives and challenges that the African continent is facing. Mzuza and van der Westhuize, (2019); Musakwa, (2017), and Sumari, Shao, and Kira, (2017) conducted studies on the status of GIS teaching and implementation in Sub-Saharan African and Southern African countries. Mzuza and van der Westhuize (2019) reported on the use of geographic information systems (GIS) in five major African regions: north, west, central, east, and southern Africa. GIS education in all of these regions is at different stages and is not uniform. These initiatives face a wide range of challenges. In some countries, GIS is taught as part of secondary/high school education, whereas in others, it is only taught at colleges and universities. Many organizations are involved in the implementation of GIS technology in tertiary institutions as well as secondary schools. African Association for Remote Sensing of the Environment (AARSE), International Society of Photogrammetry and Remote Sensing (ISPRS), and International Society of Photogrammetry and Remote Sensing (ISPRS) are among these organizations. These organizations work with a number of other international societies and organizations, including the IEEE Geosciences and Remote Sensing Society (GRSS), the European Association of Remote Sensing Laboratories (EARSeL), and a number of national societies (Sumari, Shao and Kira, 2017). These organizations play a variety of roles in strengthening Africa's GIS capacity. Gyamfi (2011) identifies three components in capacity building that aim to improve the diffusion of GIS technology in Africa. These include (I) providing the necessary infrastructure, (ii) increasing understanding of the value of geospatial data to support decisionmaking, and (iii) having appropriate levels and quality of education and training to meet geo-labor market demands. Through the adoption of Digital Earth technologies for spatial data infrastructure, these components will help to stimulate further growth of GIS technology. The geospatial industry believes that African educational institutes must adopt more innovative approaches in order to adapt to the rapidly changing scientific and geospatial education landscape. Many people in Sub-Saharan Africa's commercial sectors have increased their knowledge of GIS education in the professional academic domain and have helped to train more GIS users at universities (Sumari, Shao and Kira, 2017).

2.7.6.1 GIS TEACHING IN NORTHEN AFRICA

In countries such as Egypt in northern region, GIS is taught in high schools and the government is providing the required professional training for the teachers (Mzuza & van der Westhuizen, 2019). Loveluck (2012), cited by Mzuza and van der Westhuizen (2019), revealed that the challenges of GIS teaching in secondary schools resulted in learners being taught through memorization and rote learning methods. It was further observed that teachers in the northern region use the lecture method and they hardly use interdisciplinary approaches when they teach GIS in secondary schools. Some of the contributing factors have been identified as a lack of resources, such as a lack of computers, limited technical knowledge, and teachers' unwillingness to learn new technologies (Houtsonen, 2006; Kerski, 2009; González & Donert, 2014).

2.7.6.2 GIS TEACHING IN WEST AFRICA

The first earth observation satellite was launched in the West African region in Nigeria in September 2003, and there have been a number of changes in Nigeria's Surveying and Mapping industry, particularly with the introduction of satellite mapping (Adeoye, 2006 and Asiyanbola, 2014). Nigeria's private sector participation in geoinformatics has yet to be fully realized, owing largely to its National Geospatial Data Infrastructure, a basic geographic data framework on which the industry is expected to thrive, which has not yet been completed. Although the potential for private sector participation remains high, funding for the sector is limited due to the lack of a clear and concise guiding framework for both the content and its products.

Despite the problems listed above, the private sector continues to engage in the establishment of small training centers and the sale of low-level equipment such as hand-held GPS units, among other things (Sumari, Shao and Kira, 2017). Geoinformatics education in Nigeria's higher institutions began at the Postgraduate level in the 1996/97 academic year in the Department of Geography, University of Ibadan, with a pioneering student enrolment of 30 students, and was followed by Obafemi Awolowo University's Department of Geography (2002-2003) offering the M.Sc. (Research and Professional) programme for GIS. Other institutions which include GIS teaching are the University of Lagos, the Federal School of Surveying, and the ECA Regional Centre for Training in Aerospace Surveys (RECTAS) (Yusuf, 1997; Fadahunsi, 2010).

GIS in High Schools

GIS was included in high school education after the Federal Government's Education Reform of 2007 (Danjuma & Ubayo, 2014). Like any other African country, the lack of resources such as GIS laboratories and skills in teaching GIS affects its diffusion and the integration of GIS in this region. Ghana is one of the few West African countries where geographic information systems (GIS) is not taught in secondary schools (Oppong & Ofori-Amoah, 2012). Due to a lack of understanding of its significance, GIS is only taught at the university level in some West African countries (Mzuza & van der Westhuizen, 2019).

Challenges

Despite significant progress in Geoinformatics education in less than 20 years of space technology adoption in Nigeria, the critical issues currently slowing the pace of expansion are a lack of adequate and up-to-date facilities/equipment, delays in upgrading personnel training, a lack of appropriately trained teaching staff, and insufficient funding to conduct applied research studies. Furthermore, access to satellite images from Nigeria's satellite remains unreliable, so most researchers continue to rely on remote sensing data from other platforms for local studies, such as Landsat, SPOT, Quickbird, IKONOS, and others. Modern software and hardware are also a significant challenge, as there are few locally based successful software and hardware development firms due to the sector's inability to generate profits. In Nigeria, the incomplete NGDI is a major impediment to overall growth in geospatial education and application. These are critical areas that, in addition to those raised by Awoniyi (2014), need to be addressed further in order to expand GIS education in Nigeria.

2.7.6.3 GIS TEACHING IN CENTRAL AFRICA

GIS is taught in secondary schools in central African countries such as the Democratic Republic of the Congo (DRC), but not taught as a practical subject. The lack of resources and skilled teachers have been cited as contributing factors to why GIS is taught in this way in DRC. Learners are said to gain knowledge and experience outside of the classroom with the assistance of universities and nongovernmental organizations (Mzuza & van der Westhuizen, 2019).

2.7.6.4 GIS TEACHING IN EAST AFRICA

Countries in eastern Africa are said to be ahead of other regions in terms of teaching and learning GIS high schools. Uganda and Rwanda were the first African countries to incorporate geographic information systems (GIS) into secondary education (Milson et al., 2012; Akinyemi, 2015; Kimani, Kara & Njagi, 2013). GIS is taught as part of ITC courses in these countries. Government and non-governmental groups in Rwanda train secondary school teachers and give them GIS equipment (Forster & Mutsindashyaka, (2008) and Gould (2018), cited by Mzuza and van der Westhuizen, (2019). A lack of competent GIS teachers, a lack of electricity, and a shortage of computers in schools are the key barriers to successful GIS teaching and learning in Rwanda (Ayorekire & Twinomuhangi, 2012). One of the issues hampering GIS education in most Ugandan secondary schools has been highlighted as a shortage of certified teachers. Even university-educated geography teachers are reported not to study GIS as a subject at universities, creating a hurdle to GIS diffusion and integration in secondary schools (Ayorekire & Twinomuhangi, 2012).

2.7.6.5 GIS TEACHING IN SOUTHERN AFRICA

GIS inclusion and teaching in high schools in Southern Africa has been slow, with only a few countries teaching GIS in high schools. According to Mzuza and van der Westhuizen (2019) research on the state of GIS application in secondary schools in Southern Africa, only four countries (South Africa, Botswana, Lesotho, and Malawi) teach GIS in their secondary school curriculum.

SOUTH AFRICA

Geoinformatics education in South Africa has grown over time and now has a place in academia, research, government, the commercial sector, and non-governmental organizations. A geoinformatician in South Africa is someone who has knowledge and skills in the science of measuring, collecting, and analyzing geographic data, as well as the application of that data (du Plessis & Van Niekerk, 2014). The development of GIS in South Africa has not lagged far behind that of developed countries (Hall, 1999). GIS has had a significant impact on people's lives through platforms such as Google Maps, Google Earth, and location-based mobile phone services. South Africa's level of GIS application is described as having an emerging technical and human resource infrastructure capable of supporting a high level of GIS use (Hall, 1999; Fleischmann & van der Westhuizen, 2017). The following discussion focuses on GIS education and training in the educational, private, and public sectors.

Private sector involvement

From a private sector viewpoint, the Environmental Science Research Institute (ESRI) in South Africa, the country's leading GIS software seller, provides a variety of short GIS courses, as well as a certificate in Geo-Information Science and Technology, which it began offering in 2016. ESRI is also working on establishing a private higher education institution. Some of ESRI's courses have been accredited by the South African Qualifications Authority (SAQA) and the South African Geomatics Council. There are other small players in the private sector who offer GIS courses, but prospective students need to verify if they are registered to offer such qualifications by the Department of Higher Education. The GIS industry is growing as technology advances and there is needed to firmly regulate and standardize GIS curricula and qualification through bodies such as SAQA and SAGC (du Plessis & Van Niekerk, 2014; Sumari, Shao & Kira, (2017).

Government sector involvement

Various government departments use GIS extensively and support its uses at the state level. As guardians of South Africa's geospatial data, the Department of Rural Development and Land Reform, through the Chief Directorate: National Geospatial Information and Surveyor General, is at the forefront. Agriculture, Water, and Environmental Affairs are just a few of the government ministries that are using GIS. Similarly, the South African Space Agency (SANSA), which was created in 2010, is at the forefront of GIS and education development. SANSA has conducted training on the use of earth observation and crop monitoring in collaboration with institutions such as the International World Bank and the Japan International Cooperation Agency. SANSA distributes free satellite data such as Landsat and SPOT satellite imagery in an effort to boost

GIS research and teaching. Similarly, SANSA provides the "Fundisa disc," which is a collection of earth observation data, vector data, and open-source software to universities throughout South Africa for use in GIS teaching and research. The Agriculture Research Council (ARC), the Council for Scientific and Industrial Research (CSIR), and the Human Sciences Research Council are among the other research institutes driving the GIS agenda (HSRC).

Information Technology (IT) infrastructure in Higher Education

Since the early 1990s, GIS has been offered as a degree or diploma at the university level. Most universities in South Africa offer GIS education at all degree levels (Zietsman, 2002), either as coursework or through research in departments such as geography, surveying, town planning, environmental, and computer science (Van Niekerk, 2012; Musakwa, 2017). Most universities, such as Stellenbosch University, offer GIS degrees through face-to-face contact sessions, whereas others, such as the University of Pretoria's UNIGIS and Nelson Mandela Metropolitan University's UNIGIS, are taught through distance learning (Breetzke, 2007). However, logistical challenges, high dropout rates, and technical and practical issues are major impediments to distance learning GIS (Breetzke, 2007; Breetzke, 2008; Fleischmann, van der Westhuizen, & Cilliers, 2015). The basic GIS software used by most universities is ESRI's ArcGIS. Learners can, however, use a variety of opensource GIS software, such as SAGA GIS, Quantum GIS, and Planet GIS. In addition to GIS, software universities use remote sensing software such as ERDAS, ENVI, eCognition, and PCI Geomatica. It is critical that software resources in various forms be made available to traditional established universities as well as previously underserved universities (Ntshoe, 2003). Similarly, IT infrastructure, servers, networks, and desktops vary and are heavily influenced by financial resources. National research institutes with sophisticated GIS and remote sensing infrastructures include SANSA and The Council for Scientific and Industrial Research (CSIR).

GIS teaching in high Schools

In 2006, South Africa became the first country in the Southern African region to include Geographic Information Systems (GIS) as part of its Geography curriculum (DoE, 2003; Scheepers, 2009; Breetzke, Eksteen, & Pretorius, 2011; Innes, 2012). The topics taught in FET Phase are summarised on Table 2.4. The topics of GIS are tested in Geography Paper on the map work section. The GIS topics taught cover the following concepts (see Table 2.4).

Table 2.4: GIS Topics Taught in high schools in South Africa

Grade 10	Grade 11	Grade 12
Geographical Information Systems (GIS) • Concept of GIS • Reasons for the development of GIS • Concept of remote sensing • How remote sensing works • GIS concepts: spatial objects, lines, points, nodes and scales	**Geographical Information Systems (GIS)** Geographically referenced data • Spatial and spectral resolution • Various data types: line, point, area, and attribute • Raster and vector data • GIS application to all relevant grade topics • Tracing different types of data from existing maps, photographs, fieldwork, or other records	**Geographical Information Systems (GIS)** • GIS concepts: remote sensing, resolution • Spatial and attribute data; and vector and raster data • Data standardisation, data sharing and data security • Data manipulation includes the following operations: data integration, buffering, querying, and statistical analysis. • Government and private sector use of GIS • Relevance to all Grade 12 topics Create a "paper GIS" on layers of tracing paper using existing maps, photographs, or other records.

Source: (DoBE, 2011b).

Learners in the FET course are asked to make a GIS paper on layers of tracing paper using existing maps, pictures, or other materials (DoBE, 2011b). South Africa is the only country in Southern Africa where significant efforts have been made to put GIS into practice rather than just theoretical knowledge (Gould, 2018).

Challenges

South Africa has made significant strides in the education and advancement of GIs (Hall, 1999). It is a dynamic field; for example, the use of drones, volunteered geographic information, and big data is a new aspect of GIS education (Musakwa, 2017). Although the level of education and infrastructure in South Africa is advanced and nearly comparable to that of the developed world, there are challenges that limit the full potential of GIS education in the country (Hall, 1999; Archer, 2017). These difficulties are primarily related to resources (financial, human, and infrastructure resources) and the standardization of GIS education curricula (Van Niekerk, 2012). In terms of financial resources, the cost of proprietary GIS software is often prohibitively expensive, resulting in limited access to GIS facilities at universities, particularly historically disadvantaged universities in South Africa. Nonetheless, with the advent of open-source GIS software, GIS accessibility has improved. Regardless of software costs, setting up IT infrastructure such as servers, desktops, and network infrastructure is also prohibitively expensive, particularly for previously disadvantaged universities and small businesses (Ntshoe, 2003).

In terms of human resources, there are a limited number of qualified and accredited individuals available to teach GIs at the university level (Musakwa, 2017). Furthermore, because the number of GIS professionals in South Africa is limited, some jobs are filled by unqualified individuals. This has an impact on public-sector service delivery. There have also been issues with GIS professional registration. The new SAGC, on the other hand, seeks to address this (Zietsman, 2002). Furthermore, GIS curricula must be standardized in order to facilitate GIS professional registration. Van Niekerk (2012) proposes a set of core and fundamental competencies that facilitates GIS professional registration and accreditation of GIS courses. Other difficulties in GIS education include late qualification completion, a high drop-out rate, and logistical, technical, and practical issues in teaching GIS, particularly for distance learning (Breetzke, 2007). Policing and accreditation of various colleges offering various GIS courses is also a significant challenge. Other issues that must be addressed include capacity constraints, the fast-evolving nature of GIS, and a lack of skills.

South Africa high schools also confronts various obstacles despite being ahead of other countries in the region. A shortage of teaching and learning resources, such as computers, GIS software, spatially accessible data, and qualified GIS teachers, is one of these issues (Mzuza & van der Westhuizen, 2019). Additionally, there is a lack of technical support and training, as well as in-service training for geography teachers, difficult and complex GIS software, and proper teacher guidelines. Inadequate funding and infrastructure in rural and township secondary schools are major impediments to the spread and integration of GIS technology in South African schools (Rust, 2008; Breetzke et al., 2011; Musakwa, 2017; Zondi & Tarisayi, 2020).

BOTSWANA

A report by Tabulawa (2002) on map making by Geography students, implying that GIS concepts are being taught and learned in Botswana. According to Cavric, Nedovic-Budic, and Ikgopoleng

(2003), non-governmental organizations assisted in the introduction of geographic information systems (GIS) in Botswana government sectors around 1995, International organizations such as UNEP (the United Nations Environment Programme), which provided a Global Resource Information Database, have provided significant financial and technical support to GIS users in Botswana. UNESCO (United Nations Educational, Scientific, and Cultural Organization) has also provided numerous scholarships and supported seminars, while the Norwegian Development Agency (NORAD) has funded a number of GIS activities in Botswana (Cavric et al., 2003).

GIS teaching in high schools

There is limited information available in Botswana about the integration of GIS into public secondary school curricula. GIS is being taught in public secondary schools, but not as a stand-alone subject. Literature revealed that GIShas been taught in private secondary schools for a long period of time, particularly in Form 4 (Thomas, 2014).

Challenges

One of Botswana's problems with GIS teaching and learning, as it is elsewhere on the continent, is a lack of experienced personnel to teach in secondary schools (Tabulawa, 2002). In general, there is little information available about the incorporation of GIS into Botswana's secondary school curriculum. Some reports mention curriculum changes but do not provide specifics on the incorporation of GIS. In general, only a few studies on the incorporation of GIS in secondary schools have been conducted, so there is little information available about GIS education in Botswana.

LESOTHO

Although GIS is mentioned in the literature, it is not included in the Lesotho Geography curriculum (Raselimo, 2017). Certain topics in the syllabus will assist learners in grasping basic map reading skills and being able to interpret maps. These topics include technologies such as GPS, GIS, and remote sensing (Ministry of Education Training (MOET), 2009; Raselimo, 2017). Raselimo (2017) further contends that the current Lesotho secondary school curriculum's Geography syllabus does not adequately prepare outgoing students for fieldwork in order to advance their education and meet students' needs in the real world. According to Isaacs (2007), the Lesotho Ministry of Education mandated the installation of GIS software in all secondary schools and other educational institutions. The ministry also provided Internet access to all working stations by providing wireless area networks for connection in remote areas (in addition to the previously used active local area network). In terms of ICT, Lesotho's Ministry of Education is far ahead of the country's other public institutions.

Challenges

Like any other developing country, Lesotho experiences challenges in GIS teaching in high schools. Challenges that continue to affect GIS teaching and learning in the country include a lack of experienced teachers to teach GIS (caused by a high mortality rate due to the HIV/Aids pandemic) (Isaacs, 2007; Raselimo, 2017; Raselimo & Mahao, 2015; Selepe, 2016). Lesotho has very few publications on GIS education, which explains the scarcity of GIS information.

MALAWI

GIS is covered in the Malawi secondary school curriculum as part of Geography, but this curriculum is not available online for the general public to access (Mzuza & van der Westhuizen, 2019). GIS is taught in Malawi secondary schools as part of the geography curriculum (Mzuza & van der Westhuizen, 2019). GIS is taught in Form 4 of senior secondary schools. GIS interpretation, aerial photographs, and satellite images are among the topics covered in class (MIE, 2017).

Challenges

Like any other country, Malawi experiences a lot of challenges. A lack of resources and infrastructure, such as a shortage of computers and GIS software, inadequate or no Internet connectivity in many schools, and a shortage of qualified GIS teachers are just a few of the difficulties (Dzama, 2006; Mzuza, Yudong & Kapute, 2014). According to reports, teachers teach GIS topics theoretically without putting what they've learned into practice because they don't know enough about the subject.

ZIMBABWE

Although Zimbabwe still lags behind its Sub-Saharan counterparts in GIS education and training, efforts are being made to help the country catch up. The country recognized the need to improve GIS training and education at various institutions and has made efforts to introduce educational and training courses.

Private Sector Involvement

The Geo-Information and Remote Sensing Institute (GRSI) of the Scientific and Industrial Development Centre (SIRDC) has been instrumental in providing GIS education and training in Zimbabwe (Fazekas 2005). The GRSI focuses on natural resource management, earth and water resource management, land administration, and facility management. Training has also been provided through the assistance of foreign professionals. Australia, for example, has aided local governments in implementing Geographic Information Systems (GIS). This has resulted in GIS training for staff members in the local authorities of Gweru, Kadoma, Chinhoyi, and Kariba (Sumari et al., 2019).

Government Involvement

The government has pledged to fund GIS training in institutions through State Universities. The University of Zimbabwe, for example, upgraded its GIS diploma course in 2012 to a full-time 4-year undergraduate degree program. Furthermore, the University of Zimbabwe (UZ), the country's largest academic institution, has a Geoinformatics and surveying department that was established in 1986 and it offers education in Geodesy, Mine Surveying, Engineering Surveying, Photogrammetry, Remote Sensing, Cartography, and Geographic Information Systems (Sumari, et al., 2017). For several decades, the UZ's Department of Rural and Urban Planning (DRUP) has offered GIS to prepare its graduates for the workforce, however the course mostly addressed the fundamentals and was only offered as a one semester module during the second year. Several town planning graduates, on the other hand, have gone on to specialize in the topic, completing additional courses and degrees at higher levels, and becoming GIS experts. Other institutions of higher learning, such as the Midlands State University (MSU), the Chinhoyi University of Technology (CUT), the National University of Science and Technology (NUST), and the Great Zimbabwe University (GZU), have recognized the value of GIS and have incorporated it into a variety of programs, particularly those in the faculties of natural and social sciences Sumari, et al., 2019).

GIS teaching in high schools

GIS and Remote Sensing was introduced in the secondary schools geography curriculum in 2017. The topics of GIS and Remote Sensing are taught in Form 5 and 6 (“A’ Level) which is an exit form to universities. The topics are tested in Paper 3 of the examination at the end of two years.

It was adopted because of its ability to bring the world in the classroom (Firomumwe, 2021)

Challenges

However, in a difficult economy, Zimbabwe has experienced high levels of brain drain. In 2006, an estimated 3 million of Zimbabwe's 14 million people, the vast majority of whom were professionals, were living outside the country (UNDP, 2006). This figure could have risen over the last decade as professionals continue to flee the country in order to avoid the economic meltdown. GIS education and training have not been immune to the effects of brain drain in the country, with professionals migrating to neighboring countries such as Namibia and South Africa. As a result, there is a significant gap in both GIS academic education and professional training, necessitating the introduction of better methods to meet these needs. Like any other developing countries, GIS teaching in secondary schools faces a lot of challenges. These challenges include teacher's lack of knowledge and skills on GIS and RS, lack or physical resources such as GIS laboratories, computers, GIS software, data, lack of internet connectivity, lack of electricity (Firomumwe, 2021). These limited resources force the teachers to teach GIS lessons theoretically instead of teaching some of the topics practically as is required by the curriculum.

Despite these disadvantages, the future of GIS Education and Training in Zimbabwe looks promising. Despite the harsh economic conditions, continued efforts indicate that the country is poised to improve, relying on several assets, including a relatively young population, a highly educated diaspora, and regional connections within its sub-regions, particularly with its proximity to South Africa (ADB, 2002).

2.8 REASONS FOR PARTICULAR PEDAGOGICAL APPROACHES TO TEACHING GIS

One of the critical questions in this research relates to investigating the reasons why teachers teach GIS in particular ways. Rosenberg, O' Donoghue and Olvit (2010, p.125) suggested three factors that influence how teaching methods/strategies are chosen and used; these three factors are elaborated on below.

- One's views of education: whether education is viewed as a way of getting others to change their behaviours and actions, or to transform them, or to maintain the status quo.
- One's perspective on knowledge: whether knowledge is fixed and certain, or something learned in order to pass an exam, or dynamic, co-constructed, and changeable.
- One's perspective on learning and learners, including whether they are empty vessels waiting to be filled, active minds anxious to make sense of anything, or core learners, the educator's job, and how people learn.

Teachers who view learners as "empty vessels" waiting to be filled with knowledge use teacher-centred pedagogical approaches and teach according to lecture, questioning and explanation methods, which do not allow learners to fully participate and construct their own knowledge. On the other hand, teachers who view learning and learners as dynamic, tend to use learner-centred pedagogical approaches and use teaching methods that allow involvement of learners in the construction of knowledge in the class (Serin, 2018). Killen (2012) suggested that learners learn more effectively if teachers apply or use constructivist approaches when teaching. Constructivism classroom activities include reciprocal teaching/learning, which allows pairs of learners to teach each other, inquiry-based learning (IBL), in which learners pose their own questions and seek answers through research and direct observation, problem-based learning (PBL), and cooperative learning, all of which promote and instill independent thinking and allow learners to construct their own knowledge while actively participating in the learning processes (Kinniburgh, 2010).

2.9 TEACHERS' GIS CHALLENGES IN HIGH SCHOOLS

Teaching GIS in high schools is characterised by challenges. These challenges differ from country to country, depending on the level of development of a country, and they include a lack of physical resources, such as computers and software, a lack of competence and knowledge by the teachers, resistance to adopting new technology by the teachers, and time constraints. This section addresses some of the challenges that geography teachers in both developed and underdeveloped countries encounter when teaching GIS.

GIS diffusion in schools remains very limited at the national, regional, and international levels. It is necessary to determine why it is not diffusing at the expected rate. Providing schools with a large number of computers, according to Demirci and Karaburun (2009), does not guarantee that educational goals for incorporating technology into the curriculum will be reached. According to numerous researchers, many countries have failed to integrate GIS into their educational systems (Dooley, 1999; Scheffler & Logan,1999; Russell, 2003; Ottesen, 2006; Eteokleous, 2008; Keengwe & Onchwari, 2008). Despite reports of an increase in the number of computers in schools, their widespread use in classrooms has not occurred (Scheffler & Logan,1999; Eteokleous, 2008). Instead, as Watson (2001) points out, teachers own and use computers for administrative purposes but never use them in their classrooms. Furthermore, GIS has been widely promoted in the United States but as noted by Zondi and Tarisayi (2020), its diffusion to the rest of the world is minimal. According to studies, simply providing technology to teachers and learners in schools and classrooms is insufficient to achieve educational goals and ensure that technology contributes to teaching and learning (Demirci & Karaburun (2009). According to research, the use of technology, particularly GIS, is generally hampered by certain barriers (Scheffler & Logan,1999; Watson, 2001; Ottesen, 2006; Hew & Brush, 2007; Zhang, 2007; Keengwe & Onchwari, 2008; Mzuza & van der Westhuizen, 2019; Mkhongi & Musakwa, 2020; Zondi & Tarisayi, 2020).

Ertmer (1999) divides these barriers into two types: external and internal. External barriers include a shortage of equipment, unreliability of equipment, a lack of technical support, and other resource-related concerns, whereas internal hurdles include beliefs about teaching and mastering new technologies at the school and teacher levels. Hew and Brush (2007) identified 123 barriers to technology integration in schools, categorizing them into six major categories: resources, knowledge and skills, institutions, attitudes and beliefs, assessment, and subject culture.

GIS has also been shown in research to be a branch of technology that engages learners in higher order thinking only when combined with the necessary pedagogical strategies (Lim, 2007). As a result, an examination of barriers from this angle places teachers at the centre of the success or failure of technology integration in classrooms (Watson, 2001; Ward & Ayvazo, 2016; Ottesen, 2006).

2.9.1 TIME, CONFIDENCE AND COMPETENCE CONSTRAINTS

GIS technology is relatively new and its adoption in some institutions of learning is neither well consolidated nor integrated (Kerski, Demirci & Milson, 2015). Its use and adoption are hampered in many ways by teachers' limited time and access to the resources required for effective GIS teaching in the classroom. Despite the availability of computers and software at schools, the Gorder (2008) in a project (iGuessProject[3]) notes that few schools in England use GIS. Supplies of computers in schools alone, as noted above, will not guarantee the integration of GIS (Demirci & Karaburun, 2009). Teachers' resistance to incorporating new technologies into their lessons, as well as a lack of competence, knowledge, and prior experience, are major impediments (Scheffler & Logan, 1999; Ottesen, 2006; Zhang 2007; Paraskeva, Bouta & Papagianna, 2008; Sadik, 2008). When teachers lack confidence in incorporating technology into their lessons, they tend to ignore it and return to more traditional methods of instruction (Dooley, 1999).

2.9.2 TEACHERS' INADEQUATE TECHNOLOGY SKILLS

Teachers' GIS technology skills and knowledge are, in general, limited in some countries. For instance, in most developing countries such as South Africa, Zimbabwe, Ghana etc. GIS topics are taught theoretically and in some countries are not taught at all. In those countries where GIS is taught in high schools, no practical work is integrated into theory. This problem has affected

[3] iGuessProject was a GIS project which was started in Turkey to help learners to learn GIS concepts in schools. The project was made up learners who came from different schools and they were taught GIS software and then they do a GIS related project.

the diffusion and integration of GIS at both high schools and institutions of higher learning. Research carried out by Klonari et al. (2009) shows that most European Union countries lack proper guidance on how to teach GIS. This has resulted in a large number of teachers being resentful of using GIS in geography lessons (Demirci, 2015). The sporadic use of GIS in Finnish schools is a major issue. According to Klonarri et al. (2009), computers and GIS software, as well as GIS workbooks, are available in schools, but GIS is not widely taught in schools. GIS is primarily taught by university-educated teachers who have received GIS training. In-service training, improved database access, and ready-to-use pedagogical examples of how to use GIS in schools are among the solutions proposed (Demirci, 2015).

2.9.3 LACK OF KNOWLEDGE OF GIS AND ITS USEFULNESS BY TEACHERS

According to Shin (2007), only 11% of K-12 school teachers in the United States were familiar with or had heard of GIS. Due to teachers' lack of practical GIS knowledge, there is a low adoption of GIS technology in schools (Hong ,2014). Dube (2012), Ahiaku and Mncube (2018), Malatji & Singh (2018), Mzuza & van der Westhuizen (2019), and Tarisayi (2018) all focused on educators' perspectives on GIS in schools and all agreed that most high school teachers lack GIS knowledge. According to a study conducted by Fleming (2016), as cited in Zondi and Tarisayi (2020), the majority of learners who took Geography Paper 2 in 2014 and 2015 did not answer questions about GIS. The learner's low attempt rate on GIS questions was attributed to a lack of content knowledge. Many of the learners were not adequately taught GIS topics. Mzuza and van der Westhuizen (2019) summarize the difficulties in teaching GIS in Southern Africa as follows:

“The absence of GIS education in secondary school curricula, the shortage of experienced teachers, the lack of knowledge and technical expertise, the unwillingness of teachers to change their mode of teaching, a shortage of funds and inadequate resources” (Mzuza & van der Westhuizen, 2019, p. 1).

This suggests that teachers do not know much about GIS and that is why they were expending the effort to learn about it or to teach it. The starting point should be helping teachers to understand and appreciate the importance of GIS. In order for teachers to teach any subject, they must have in-depth content knowledge and pedagogical knowledge (Shulman, 1986). Teachers should know how learners learn the subject, know the content and know how to teach it, and plan for effective teaching and learning (Shin, 2007; Höhnle et al., 2016; Jacob, John & Gwany, 2020). Teachers must understand the content, which includes, among other things, subject matter knowledge, pedagogical knowledge, and knowledge of pedagogical content (pedagogical content knowledge-PCK) (Shulman 1986). In order to consider the complex interaction between pedagogy and subject content, Shulman (1986) introduced PCK to symbolise the coming together of pedagogical and content knowledge. As a result, GIS content and pedagogy, as well as the teaching approaches or considerations involved in teaching a particular content or subject, cannot and should not be separated (Fuglesten, 2010; Jacob, John & Gwany, 2020).

In addition, Feiman-Nemser and Parker (2001, p. 40) asserts that "understanding subject matter is sine qua non in teaching" – without it, a teacher cannot function well. Feiman-Nemser and Parker (1992, p. 11) state that "learners cannot be taught to simply to think. They have to do something to think about". As a result, this requirement necessitates that the teacher be well-versed in the subject. The instructor should be aware of the structure that blends content knowledge (facts, skills, concepts, and generalization) with pedagogical knowledge (Shulman,1986). The combination of content and pedagogical understanding of how specific subject information is organized, represented, and suited to the various interests and skills of learners, and then given for instruction, is referred to as pedagogical content knowledge (PCK). (Van Dijk & Kattmann, 2007; Ward & Ayvazo, 2016). The interaction between the content matter and pedagogy is, thus, very important (Shulman, 1999).

The tenets of pedagogical content should be considered further here. Shulman (1996, p. 10-12) states that:

"Pedagogical content knowledge (PCK) also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that learners of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons".

PCK includes knowledge on how to teach the content, so that it can be easily understood.

PCK is thought to be multidimensional, implying that the construct can be investigated on multiple levels. In this study, two types of PCK had relevance: personal PCK and canonical PCK (Gess-Newsome, 2015). Personal PCK differs from teacher to teacher and from context to context. Personal PCK refers to teachers' knowledge of the subject and how they apply it to the benefit of the learners. This personal PCK is important in the teaching of GIS in high schools. Without personal PCK, teachers tend to struggle to teach the content to the learners, because the teacher will not be confident about explaining the concept to learners. The danger of the teacher not having comprehensive content knowledge of what he or she teaches is that the teacher may teach incorrect information to the learners, leading to misconceptions about the subject (National Research Council, 2006; Jacob, John & Gwany, 2020). Canonical PCK, on the other hand, refers to PCK that is "based on the topic being taught and is part of the body of knowledge established by the science education profession as good practice" (; Shulman, 1987, p. 9; Garritz, 2015, p.79). In this regard, the teacher must have in-depth knowledge of the topics he/she is teaching. Park and Parker & Oliver, (2008, p. 262) stated that for the teachers to effectively use PCK, the teacher must be aware of what the learners already know about the topic and the areas in which the learners are likely to encounter some difficulties. The PCK component is knowledge of learners' understanding of science, which includes learners' conceptions of specific topics, learning difficulties, motivation, and ability diversity, as well as learners' learning styles, developmental levels, and needs. Deep knowledge of the topics to be taught is important, because the teacher will be able to explain and illustrate what he/she is teaching by citing appropriate examples that can drive the point home, to the benefit of the learners in the class (Shulman, 1987).

An “amalgam” of pedagogy and content (PCK) “makes teachers different from other scholars in the field” (Gudmundsdottir, 1987, p. 4, Shulman, 1987, p.8). In this context, PCK denotes the blending of pedagogy and content knowledge of the subject to be taught to the learners. As a result, a geography teacher who is meant to teach all the content of geography, such as physical geography, geomorphology, human geography and GIS, should have a sound knowledge of the subject’s PCK. PCK enables the teacher to transform the subject matter in ways that will make it easy for learners to understand. The “transformations of preparation, representation, selection, adaptation, and tailoring of the content matter to the characteristics of the learners necessitate a combination of processes, each of which employs a kind of repertoire" (Shulman, 1987, p. 16). Furthermore, according to Shulman (1987, p 17), the "ability of the teacher to prepare the subject matter to the levels of the learners of any grade is the act of pedagogical reasoning," teaching as thinking, and planning – expressly or indirectly – the delivery of instruction is the act of pedagogical reasoning which is expressed in different ways by the teachers.

In addition to the problems mentioned above, PCK in GIS at high schools is hindered in certain ways by limited time and restricted access to the resources necessary to learn the complications of a GIS software package, such as ArcMap. For instance, GIS and software are available in most schools in Finland, but GIS is not widely taught in schools (Klonari et al., 2009). Some of the difficulties that teachers face when attempting to implement GIS include a lack of funds to purchase physical infrastructures such as computers and GIS software, which remain relatively expensive in the South African market (Nxele, 2007), as well as educators' lack of GIS knowledge, particularly in the practical aspects of GIS, which is a significant challenge in most teachers and schools (Zietsman, 2002; Siegmund et al., 2007; Zondi & Tarisayi, 2020).

2.10 CONCEPTUAL AND THEORETICAL FRAMEWORKS OF THE STUDY

The following section explains the conceptual and theoretical framing for this study. This research study will be viewed through the lens of Rogers' (1995) diffusion of innovation (DOI) theory, and Legris' (2003) Technology Acceptance Model (TAM). The theoretical ideas presented in them will be used to formulate the conceptual framework of this study, and to argue in this thesis that technological innovation, like GIS, is used by teachers when it is seen as useful, and when there are no barriers to integration and that the adoption/diffusion processes takes time due to certain disabling factors and as such diffusion happens through a number of stages before the innovation is fully integrated. The main constructs of the DOI and TAM are described in greater depth in the following section.

2.10.1 DIFFUSION OF INNOVATION

DOI is one of the oldest social theories. This theory focuses on individual characteristics and the internal characteristics of the organisation, in this case the school, as essential requirements for organisational innovativeness (Rogers, 1995). DOI explains how an idea can, over time, gain traction and spread to places and people. According to Rogers (2003), innovations tend to diffuse through identified channels over time within a specific social system. People, as agents of transmission of this innovation, have varying degrees of willingness to adopt innovation that is normally distributed over time (Rogers, 2003). Rogers proposed four major DOI elements. These include technology (innovation) itself, communication channels, time, and social systems, all of which affect how the spread of innovation takes place in a society. The spread of innovation is heavily reliant on human capital (Chigona & Lickers, 2008). Furthermore, Rogers (2003) claims that there is a point and time when technology reaches a large number of people in terms of adoption rate. However, in order for this to occur, the diffusion of an innovation, in this case, GIS, shows itself in various ways across facets of society, and is heavily influenced by the kind of adopter and the technology decision process. As a result, understanding the factors that influence an innovation's adoption and use is one of the first steps toward increasing its rate of adoption. Furthermore, adoption and innovation use do not occur at the same rate in different social system settings.

Table 2.5: Key elements of diffusion of innovation model

Element	Definition
Innovation	a human or other unit of adoption who perceives a new idea, practice, or item (Rogers, 1983)
Communication channels	the method by which messages are transmitted from one person to another (Rogers, 1983)
Time	The length of time required to complete the innovation-decision process is referred to as the innovation-decision period (Rogers, 1983)The rate of adoption is the time it takes for members of a social system to adopt a new idea (Rogers, 1983)
Social system	a group of interconnected units working together to solve problems in order to achieve a common goal (Rogers, 1983)

According to Rogers (2003), DOI happens through a five-step decision-making process. It occurs over time among members of a particular social system through a variety of communication channels. GIS technology is expected to spread from the Department of Education to school geography teachers and then to the learners in this study. DOI incorporates Roger's five stages – awareness, interest, evaluation, trial, and adoption. The stages of the DOI process are depicted in Figure 2.6.

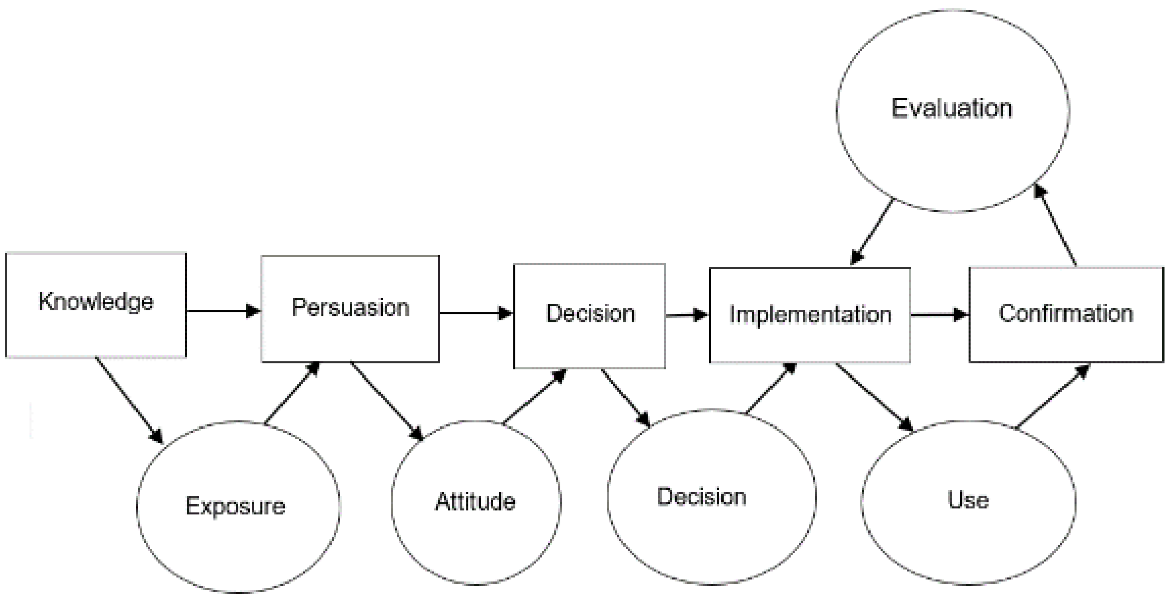


Figure 2.6: Phases of the innovation decision process

Source: Rogers (2003)

Table 2.6 explains the five stages of the adoption process shown in Figure 2.5.

Table 2.6: Five stages of adoption processes

Stage	Definition
Knowledge	The individual is initially exposed to an innovation, but he or she has little knowledge about it. At this time, the individual is not motivated to learn more about the innovation.
Persuasion	The individual is captivated by the innovation and is actively seeking related information/details.
Decision	The individual evaluates the concept of change, weighs the advantages and disadvantages of implementing the innovation, and then decides whether to adopt or reject it. Because of this stage's individualistic nature, Rogers (1962) notes that obtaining empirical evidence is the most difficult.
Implementation	People employ innovation to varied degrees depending on the situation. During this stage, the individual assesses the innovation's utility and may seek additional information.
Confirmation	Individuals are the ones who decide whether or not to use the innovation. This stage involves both intrapersonal (which can lead to cognitive dissonance) and interpersonal, but it concludes with assurance that the group made the right decision.

2.10.2 PROPERTIES OF DIFFUSION OF INNOVATION

According to DOI, the likelihood of an innovation's adoption is determined in part by its characteristics (Chigona & Lickers, 2008). The five characteristics of DOI are as follows: (a) comparative advantage, (b) compatibility, (c) complexity, (d) observability, and (e) trial-ability These characteristics are cost-effective in the sense that they relate to the amount of work required to adopt vs the costs and advantages of not adopting (Chigona & Lickers, 2008). The relative advantage provided by an innovation is another factor that must be considered. Relative advantage refers to the degree to which an innovation is judged to be superior to its predecessor. The advantage is calculated by comparing the previous method of doing things (if one exists) to the current method of doing things or doing nothing at all (Chigona & Lickers, 2008). The bigger an innovation's apparent relative advantage, the faster it will be adopted.

The other characteristic is compatibility. The degree to which an innovation is seen to be compatible with current social ideals, needs, and prior experiences of potential users is referred to as compatibility. In this case, for GIS to be adopted, it has to be compatible. For instance, if the school has an ICT lab, GIS software can easily be installed on the computers that are available, so that geography learners can do the practical activities and assignments or projects.

The other attribute/factor that affects the adoption of technology is the complexity of the technology. The complexity of an innovation is defined as the degree to which it is thought to be difficult to comprehend and apply. This trait negatively related to the rate at which an innovation is adopted and spread in society. If the innovation is perceived as difficult, its diffusion will be slow and, in some cases, stagnant, as people will resist adopting it.

Observability refers to the degree to which the outcomes of an innovation are visible to others. Others can easily see the outcomes of adoption by people who have already adopted the technology if it helps or makes their lives easier. People will be enticed to adopt it in their lives if the consequences of innovation can be observed by other people changing their ways of doing things for the better.

The final characteristic of innovation adoption is its ability to be tested and produce positive results. The extent to which an innovation can be tested without undue expense or with limited resources prior to adoption is referred to as trialability. Trialability is sometimes linked to an innovation's divisibility (Niederman, 1999). The degree to which an innovation can be embraced in stages, with each phase potentially leading to greater adoption, is referred to as trialability/divisibility (Niederman, 1999). Cultural values, job and its related stress, and societal issues can all impact adoption. Inherently, innovations that can be tried in portions are more trialable than those that need knowledge of the complete technology before being employed. As a result, people are more likely to adopt an innovation if they believe it will improve their social standing.

2.10.3 ROGERS' DIFFUSION OF INNOVATION THEORY

Rogers' DOI theory is applicable to this study, as it highlights the stages that are followed when technology is adopted. Rogers (2003) states that, for technology to spread effectively, the diffusion has to follow certain stages, and, to avoid resentment among adopters, these stages have to be clear and easy to follow. This is true for the adoption and use of GIS at high schools. The stage at which GIS technology diffusion is, is not clear (Siegmund, et al., 2007; Chen, 2012; Manic et al., 2013). In addition, most schools and teachers lack knowledge about GIS because of their historical backgrounds, which vary from one school to the other and, hence, the rate of implementation of this technology is uneven (Mabuza, 2019; Zondi & Tarisayi, 2020). Schools in rural areas and townships (quantile 1-3 schools) are under-resourced compared to former Model C schools and private schools (quantile 4-5). These differences in resource availability affects the rate of diffusion of GIS technology and the way it is taught to the learners (Du Plessis & Mestry, 2019).

2.10.3.1 COMMUNICATION CHANNELS

An innovation can be communicated via mass media (the internet, radio, and television) or through interpersonal communication. These channels serve different purposes and complement one another in some way. While many people may first become aware of an innovation through the media, interpersonal (person-to-person) communication is more likely to influence adoption decisions (Chigona & Lickers, 2008). The job and its description define relative advantage, whereas observability determines the ability to communicate results to others, complexity determines the ability to discourse to oneself about what one is doing, and trialability determines the trial's social circumstances. If the innovation is intended to be employed in communication, all of these aspects are boosted.

2.10.3.2 TIME TAKEN TO ADOPT

The adoption curve time is spherical (S-shaped). Based on when they adopt it, people are classified as innovators (those who adopt an innovation as soon as possible), early adopters, early majority, late majority, or laggards (those who never adopt). Innovators typically take risks, and because they are the first to adopt, their decisions are not influenced by others (Rogers, 2003). Early adopters, as opposed to innovators, are down-to-earth and often well-liked in their communities (Chigona & Lickers, 2008). Because of these characteristics, early adopters usually urge others to accept an innovation. Laggards are the last to adopt, if at all, and they frequently lack the financial resources to do so. They may, however, be forced to adopt it if the cost is not too great (economic or otherwise). As indicated in Table 2.5 adoption proceeds through the five stages of the adoption decision process.

2.10.3.3 RATE OF ADOPTION

The pace of adoption relates to how rapidly a new technology is adopted. It is based on how long it takes a specific percentage of a social system's members to accept an innovation (Rogers, 1962, p. 134). The rate of innovation adoption is determined by an individual's adopter category. People who are among the first to adopt a new technology have a quicker adoption period (process) than those who are late adopters. According to Rogers, an innovation hits critical mass when the number of individual users ensures the innovation's self-sustainability (MacKeracher et al., 2019).

2.10.3.4 ADOPTION STRATEGIES

Numerous strategies can be implemented to help an innovation to reach different stages of adoption. One technique is for a highly respected individual in a social network to adopt an invention, causing others to develop an instinctual desire for that innovation. Injecting an idea into a group of people who would readily employ it and offering positive incentives for early adopters are two more beneficial tactics.

Adoption is an individual process that takes place according to a series of stages that someone passes through, from the first time you hear about an idea through the day you put it into practice (MacKeracher et al., 2019). Thus, diffusion denotes a set of phenomena that indicate how an innovation spread.

2.10.4 ACCEPTANCE VERSUS ADOPTION

The terms adoption and acceptance are sometimes used interchangeably in literature, but there is a significant difference between the two. Kollmann addressed this distinction in 2004. According to him, adoption and acceptance are two stages of the acceptance process. The three stages of the acceptance process are depicted in Figure 2.7.

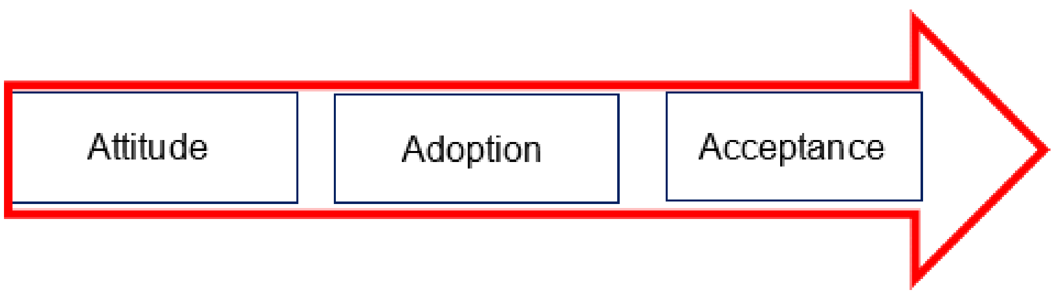


Figure 2.7: Steps in accepting new technology

Source: Kollmann 2006

2.10.4.1 THREE MAIN STEPS OF THE ACCEPTANCE PROCESS

According to Kollmann (2006), the process begins with the "attitude" phase. This phase includes the steps of becoming aware of the technology, developing an interest in it, and evaluating it. The second phase is the "adoption" phase, which includes the technology's trial, purchase, and implementation. According to Kollmann (2006), the adoption phase concludes with a decision to use the technology or with its first use. Furthermore, the decision to use (or the first use) is regarded as the initial step in the acceptance phase. The first use of the technology is viewed as the final step of the adoption phase in this study.

The third phase, the "acceptance" phase, is when the technology is actually used on a continuous basis until it is no longer useful. This phase includes an evaluation of the technology's use and (witting or unwitting) periodic decisions about whether or not to continue using it (Sahin, 2006, p.18-21).

2.10.4.2 ADOPTION MEASUREMENT

Adoption occurs at a specific point in time, implying that it can be measured through a survey. The inclusion of the first use moment in the adoption phase indicates that high schools that use GIS (after implementation) have adopted GIS.

Rogers' (1995) adoption curve can be used to track the progress of GIS adoption. This graph depicts the rate of adoption over time. Figure 2.8 based on Rogers, shows that innovation is adopted in stages, and these stages take time to be accomplished. The time taken at each stage depends on a number of factors (Sahin, 2006, p.19). These factors include among other factors such as the availability of information on that technology. If the information on how to use such technology is readily available, the people expected to adopt the innovation can easily adopt it. Also, equipment involved in the innovation place an important role. Some equipment on which technology operates are expensive to buy and to install, as such, the adopters find it expensive to adopt such technology and as a result that technology will take long to be adopted and used by the intended users because of the exhibitive cost to run the technology. The other factor is the willingness of adopters to learn and adopt the innovation. In most instances the adopters are the ones who are not willing to learn and adopt the new technology despite the availability of the technology (Sahin, 2006). The adoption of GIS technology seems to lag behind in most underdeveloped countries, compared to developed countries. The diffusion of an innovation in any given society depends on earlier adopters (Figure 2.8). A strong foundation has to be established first, before a take-off can be realised, thus, a great deal of information and physical equipment should be in place.

The acceptance and diffusion of GIS in high schools in South Africa seems to be lagging due to a number of factors according to the literature. These factors include a lack of physical resources, such as computers, software, laboratories and skilled teachers to teach GIS in high schools. Above all, the attitude of the adopters (in this case, geography teachers) will influence diffusion of GIS in geography teaching. This problem is not limited to South African high schools. Schools in developed countries, such Japan, the United States and Turkey, experience similar problems (Kerski, 2008; Demirci & Karaburun, 2009; Mzuza & van der Westhuizen, 2019; Zondi & Tarisayi, 2020; Mkhongi & Musakwa, 2020).

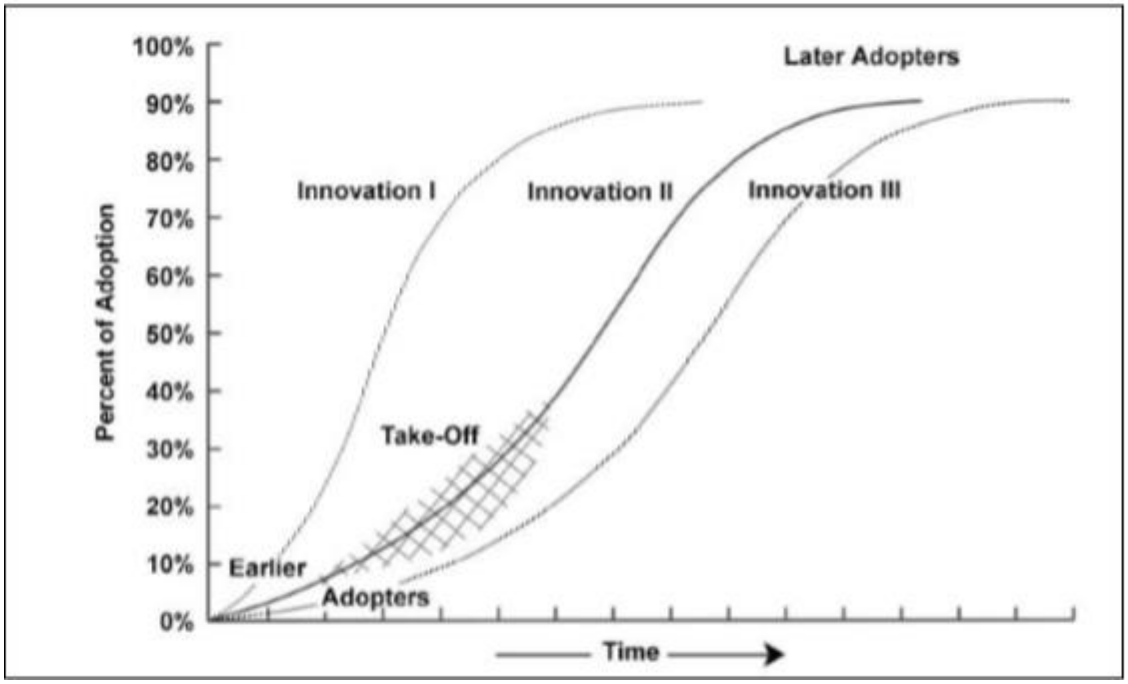


Figure 2.8: Roger's innovation adoption curve

Sources: Rogers (1995, p. 11); White (2005, p. 42).

2.11 TECHNOLOGY ACCEPTANCE MODEL (TAM)

TAM is an information systems theory that explains how people come to accept and use technology. When users are faced with new technology, the model argues that a variety of factors impact their judgments. As a result, this approach is founded on two principles: perceived technology usefulness and perceived ease of use.

Perceived usefulness of technology

Perceived usefulness refers to an individual's belief (Chen, 2010; Teo & Lee, 2010; Isaac et al., 2016) that by employing/using a particular technology will improve his or her job or life performance. If GIS technology is seen as a useful teaching tool, certainly teachers will try to adopt the technology and use it in their lessons when teaching other topics of geography. The model suggested that usefulness of the technology will positively enhance good attitude of the teachers towards the technology. Positive attitude will positively influence the behaviour of the individual to adopt the technology.

Perceived ease of use

Perceived ease of use of technology refers to a person's belief that a specific information system or information technology will be painless to use (Chen, 2010; Isaac et al., 2016). These two principles play a role in influencing a person's behaviour or actions. The ease of use and perceived usefulness of an information system have a positive impact on people's attitudes toward it, as well as their intentions to use and accept it (Chen, 2010).

This model was chosen because it helps me to understand how technology, such as GIS, diffuses and is accepted by geography teachers in high schools. It is assumed that, if technology is accepted easily in society by the intended population, the adopters, in this case teachers, would improve their ways of teaching GIS to learners. If geography teachers who are adopters believed that GIS can add value to whatever they are teaching in geography, they would be more likely to aid its diffusion to learners and the rest of the society. The lens of this theory helped me to unpack the attitudinal tendencies and perceptions of teachers, which inform the pedagogical approaches these teachers use to teach GIS. For instance, if geography teachers perceived GIS to be a technology that is difficult to use, and one that is unlikely to improve the teaching of geography, teachers would fail to exert the effort to teach GIS – this effect relates to the pedagogical choices of teachers.

What I drew from the TAM and its extensions is that the technology of GIS can only diffuse into geography teaching if teachers have the right attitude towards adoption. For instance, if geography teachers perceive GIS to be a useful technology that is easy to use, they would willingly institute initiatives without being forced to do so, and they would use it in their geography lessons apart from just teaching the section titled GIS. However, if teachers fail to see its usefulness to teaching geography, geography teachers would be hesitant to adopt it, and they would find other methods of teaching geography and may not even teach GIS as a section with any effort. Teachers would teach the GIS section in a way that merely ensured that learners passed the examination. If geography teachers realise the immediate benefits of GIS for geography, they will find ways of improving their pedagogical approaches when delivering GIS lessons and infuse GIS into their general Geography lessons. Unless they realise the benefits, using GIS as a technology in geography classes will continue to have limited adoption by teachers, owing to the teachers' negative attitude towards this technology. Figure 2.9, the TAM highlighted some of the factors which influence the acceptance and diffusion of GIS technology in high schools.

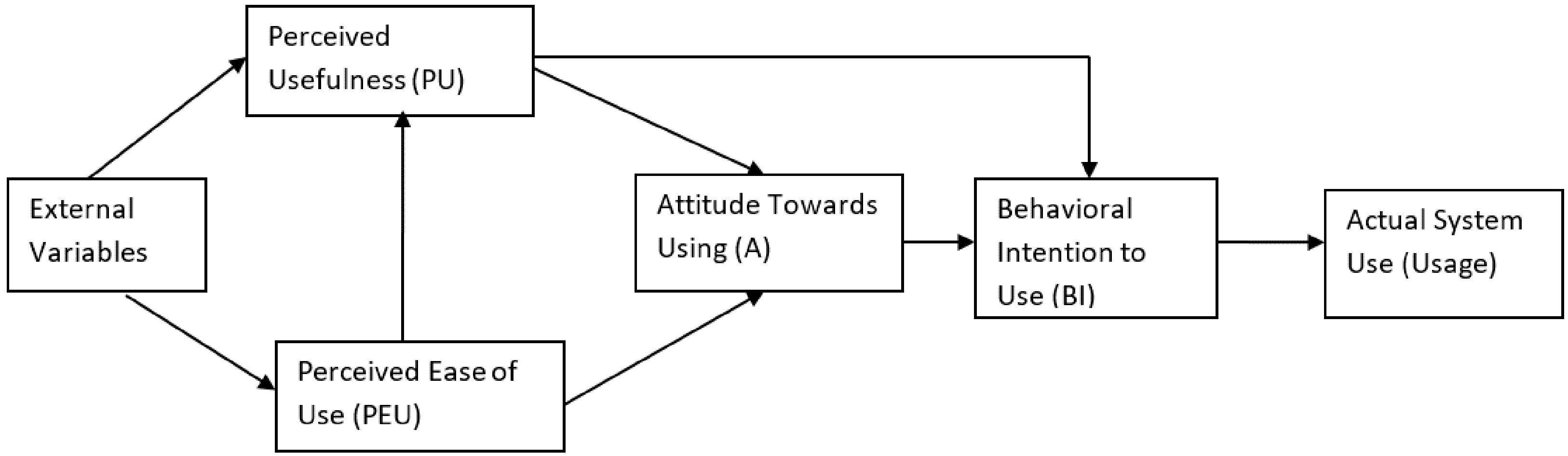


Figure 2.9: Technology acceptance model

Source: Legris (2003)

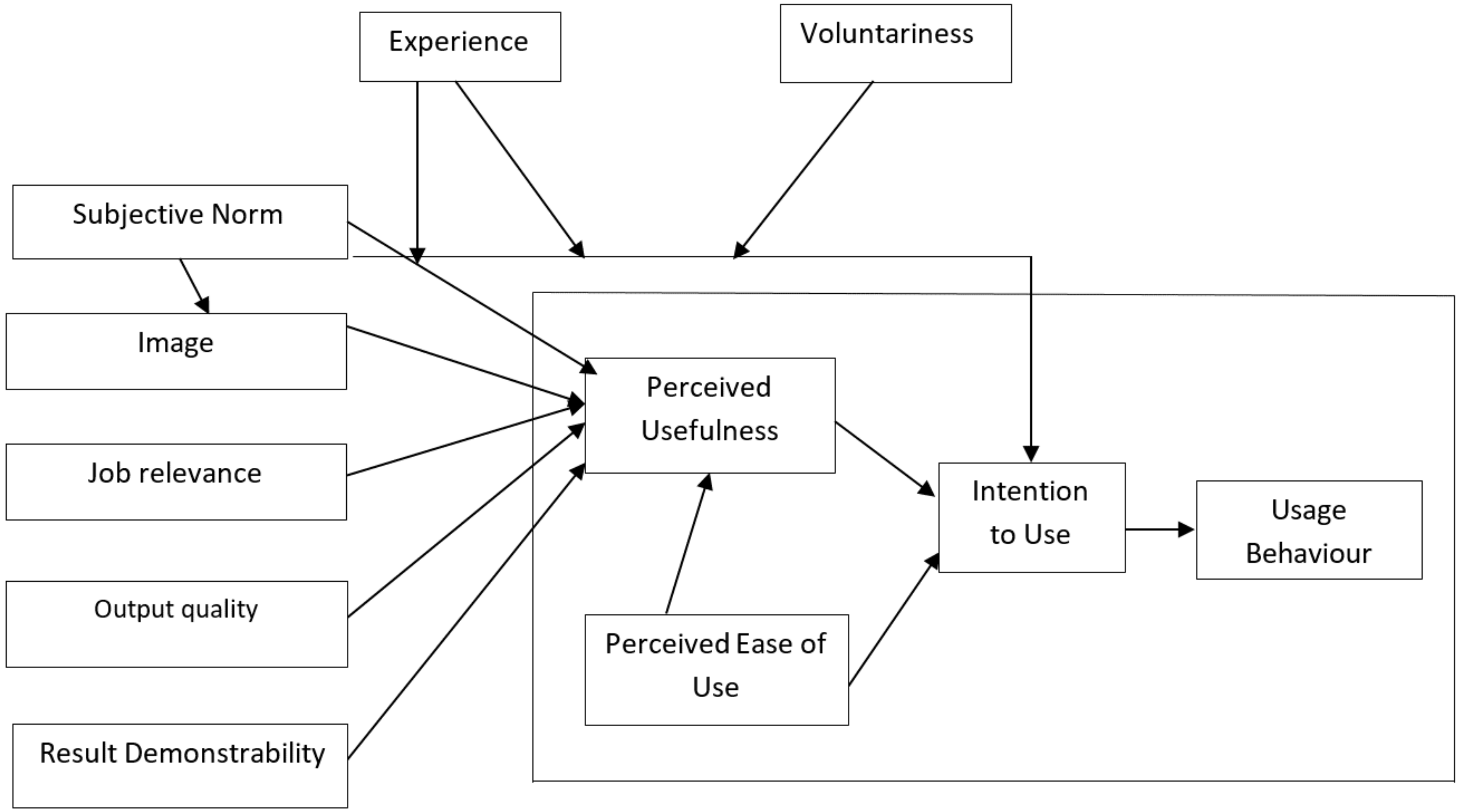


Figure 2.10: Theoretical extension of the technology acceptance model

Source: Venkatesh and Davis (2000)

It is suggested that teachers will not necessarily put effort into learning GIS software, even if they can download it free of charge and use it in class. The theory of planned behavior (TPB), which connects one's beliefs and behavior, is critical to technology adoption and use. The TPB will shed light on and provide answers to some of Rogers' (2003) questions relating to why some people adopt and accept technology, while others lag behind, and some choose not to adopt it at all.

2.12 LIMITATIONS OF THE TECHNOLOGY ACCEPTANCE MODEL

The TAM has limitations, among which are:

- Regardless of the user's purpose, the model assumes that a person has gained the opportunities and resources necessary to be successful in doing the desired behaviour.
- Other factors that influence behavioural intention, such as fear, threats, mood, or past experiences, are not taken into account by the model.
- While the theory takes moral influences into account, it ignores environmental or economic elements that may impact a person's decision to engage in a behaviour.
- It implies that behaviour is the outcome of a sequential decision-making process and ignores the possibility of change across time.
- The theory does not address the time period between intention and behavior action. (Teo & Lee, 2010, p. 120).

I will focus on the second to fourth limitations mentioned above because I think these are more appropriate and applicable to my study. The model does not consider the threat caused by fear and past experiences as factors that could affect someone's attitudes and behaviour. Many people are afraid of trying new technology. In addition, the environment in which a person operates has a great bearing on their attitudes and behaviour (Buć & Divjak, 2016). Thus, a person who is surrounded by people who use technology is more likely to adopt technology too. Furthermore, people's behaviour does not progress in a linear fashion, yet the TAM assumes that, if someone develops the correct attitude, then the person will develop the right intention, which will then influence his/her behaviour, and consequently adopt technology simply because he/she has the right attitude and intention.

The benefits GIS can offer to learners and teachers in high school have not yet diffused as expected in many countries and this is a cause of concern to many geography academics in the world. The question that needs to be addressed is why it is not diffusing at the rate anticipated. Despite the fact that schools in South Africa have not been provided with computers to teach GIS practical exercises and it is not tested practically during the examination, Demirci (2008) appears to imply that providing huge numbers of computers to schools does not ensure that educational aims to integrate technology into the curriculum would be realized. According to studies, various countries have failed to integrate ICT into their educational systems (Dooley, 1999; Scheffler & Logan,1999; Russell, 2003; Ottesen, 2006; Eteokleous, 2008; Keengwe & Onchwari, 2008). Despite reports that the number of computers in schools is increasing, computers are still not commonly employed in many countries' classrooms. (Scheffler & Logan,1999; Eteokleous, 2008; Zondi & Tarisayi, 2020; Mkhongi & Musakwa, 2020). Hence, GIS has been slow to diffuse into high school geography classrooms in the United States and elsewhere (Bednarz & Ludwig, 1998; Mzuza & van der Westhuizen, 2019). A study done by Mzuza and van der Westhuizen, (2019) about the current condition of GIS use in secondary schools in Southern Africa revealed that only 4 countries in the region teach GIS in high schools. This shows how slow the diffusion of GIS education is in this region and elsewhere.

Finally, according to Demirci (2008), just putting technology in the hands of instructors and learners in schools and classrooms is insufficient to ensure that it is used to enhance teaching and learning. Therefore, technology must be integrated effectively into instruction. In addition, attention should be paid to the attitudes of educators, and pedagogical issues relating to the adoption and teaching of new technologies, such as GIS.

2.13 STRATEGIES TO TECHNOLOGY DIFFUSION AND ACCEPTANCE

There are many strategies which can be adopted and implemented to make technology such as GIS diffuse and be accepted easily. These strategies include identifying innovators of technology (Rogers, 2003). These innovators of the new technology can be mentoring the other colleagues who lack the knowledge about the technology. For example, the earlier adopters of the new technology such as GIS may share their knowledge with the novel teachers on how they can implement and adapt to the new technology by sharing their lesson plans, new forms of assessing and monitoring of the learners about the technology (Wilson and Conyers, 2015). In this case, GIS innovators (teachers) can be identified in various high schools and be tasked to mentor other teachers (earlier adopters) on the technology. The strategy can help to make the diffusion of technology trickle down easily and fast when the technology is brought and implemented by their peers (Hartman, Townsend & Jackson, 2019; Mirvis et al., 2006). Also, if the teachers see the technology being used and implemented by their peers, they may feel more comfortable and willing to try the technology. The teachers who will be mentored will become the earlier adopters of the technology and it can snowball to the rest of school. (Wilson & Conyers, 2015).

2.14 EDUCATORS' ATTITUDES TOWARDS GIS

The other critical question this research sought to answer is: What are teachers' attitudes towards GIS in geography in the FET curriculum? In trying to answer this critical question, I explored the attitudes of teachers in an attempt to understand whether attitudes influence the way GIS is taught in high school geography. Attitude, as an element of the affective domain, is an important factor that influences teaching and learning and, ultimately, affects the overall performance of learners of a subject. I want to begin this section by this quotation:

The Science of Education is an area of expertise formed on the basis of two notions, "education" and "instruction" (Kerski, 2007 cited by Uluga, Ozdenb & Eryilmaz, 2011).

Education, as it has been defined over the centuries, is the activity of assisting young generations in obtaining important information, skills, attitudes, and understanding that aids in the development of their character while also preparing them to function and contribute meaningfully to the society in which they live (Hartman, Townsend & Jackson, 2019; Kerski, 2007 cited by Uluga et al., 2011). Teaching, on the other hand is regarded as a process that individuals develop and acquire during the education phases in their lives. This acquiring of knowledge depends very much on the capacity and attitude of the teacher. For learners to learn skills and knowledge in any subject, hinge on the attitude of the teacher to motivate the learners (Omolara, 2015). In this whole matrix of education, teaching depends on the teachers' attitude towards the subject. In general terms, a teacher is somebody who works in educational institutes and who assists learners/learners to reach their cognitive, sensory development and advances their potential within the parameters stipulated by the educational system (Uluga et al., 2011).

A review of literature of the construct of attitude found that many definitions relate attitude to other psychological constructs, such as beliefs, values and opinions (Manyatsi, 1991). Attitude is defined as "a mental or neural state of readiness organised through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related" (Baker, 1992, p. 256). In other words, attitude refers to the mindset of an individual, disposition to certain ideas, and how the person thinks and act (Omolara, 2015), about people, systems, institutions, technology software such as GIS etc. People's attitudes about something can influence their behaviour and performance. Negative attitudes toward one's job can lead to poor performance. Similarly, "attitude may influence how well a teacher plans and prepares for his or her lessons" (Omolara, 2015, p. 131). Omolara went on to say that a teacher's attitude, whether conscious or unconscious, influences learners' academic performance in a variety of ways. If a teacher is uninterested in a subject or topic, he or she will be unable to create a positive learning environment. Also, teachers who have a negative attitude towards a subject may be very difficult to approach for further explanation and clarity on certain issues. In this regard learners find it difficulty asking such a teacher question on areas they did not understand. Attitudes have several components, which are discussed briefly below.

- **Cognitive component**: This represents our thoughts, beliefs and ideas on something. These thoughts and beliefs may come to light as generalities or stereotypes. Cognitive component is “associated with the knowledge” (Čvirik, 2021, p.25). This knowledge, coupled with any prior experiences of the geography teacher in trying to use GIS, can be applied to evaluating future adaption and use of GIS in the classroom.
- **Conative or behavioural component**: This is the tendency or nature of a person to act in certain ways in relation to something (Čvirik, 2021). Although the emphasis is on the proclivity to act rather than the actual act, what we plan and what we do may be quite different. In this research the geography teacher may portray good attitudes towards GIS inclusion in the geography curriculum and they may show different attitudes during the lesson delivery. These different conative behaviours might be shaped by lack of the resources which makes the teacher to behave in a certain way
- **Affective component**: This refers to feelings or emotions, such as fear, sympathy or hate, that are evoked by something (Okwilagwe, 2012, p. 6). If a person says that he/she likes GIS, the person is actually evaluating the subject he/she is referring to.

Attitude and its formation

Attitudinal formation is defined by several motivational bases (Omolara, 2015). David (2013) cited by Omolara (2015) stated that there are four motivational underpinnings for attitude formation: utilitarian formation, value-expensive formation, ego-defensive formation, and knowledge formation. Individuals' survival, safety, and other social necessities are all tied to utilitarian attitudes. As a result of this research, the geography teacher's attitude toward teaching and studying GIS is likely to be favoured if GIS enhances the instructors' survival needs. In this case the teacher will adopt GIS if it enhances his/her chances of remaining relevant at the workplace by improving his competency in teaching the geography subject. A person's ego-defensive attitude is a strategy for them to maintain their concerns. The inference is that teachers who are upset with technology as well as their teaching settings and atmosphere are more likely to have a negative attitude toward their learners' instruction and learning (Omolara, 2015). A person's intention for self-esteem and self-actualization is at the heart of their value expressive attitude. This means that having an attitude that aligns with one's values and beliefs will increase one's self-esteem. Knowledge is the last one. This is critical in dealing with the attitudes of individuals around a person who share one's viewpoint on the subject matter being studied or the teacher is teaching.

Attitudes of teachers towards teaching GIS in secondary schools

GIS is a framework for data collection, management, and analysis (ESRI, 2019). GIS is a geographic information system that incorporates many sorts of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenarios. GIS education, particularly in high schools, continues to face numerous issues around the world. GIS is a difficult subject that can only be handled by teachers who are well-trained and skilled (Demirci & Karaburun, 2009). This section is an attempt to find out how attitudes of teachers affect its diffusion. There is a high connection between attitude and the way GIS is taught by the teachers in classroom.Teachers' attitudes affect their choice of pedagogical approach, their effort, as well as the level of enthusiasm they experience for what they are doing (Kubiatko, Janko, & Mrazkov, 2012; Omolara, 2015). According to Semerci & Aydn (2018), educators' attitudes toward technology are influenced by the person himself/herself. The humanistic approach to technology integration is defined as involving the whole person and manifesting itself in a variety of ways, including the individual's values, beliefs, confidence, and emotions. Teaching as a profession is a humanistic endeavour and a teacher finds joy when he/she interact with his /her learners in the class when sharing knowledge with them. It is the teacher who bridges the gap between human and the GIS technology culture. The adoption of new technology such as GIS and the use of various pedagogies are influenced by the teachers' values, beliefs, attitudes, and level of confidence. Thus, teachers' attitudes towards the integration and diffusion of technology is very important to the adoption and integration of technology in the lessons by the teachers. Positive attitudes play a critical role in determining whether a new technology integration is accepted or rejected (Hartman, Townsend & Jackson, 2019). Rogers (1995) asserts that people's attitudes towards new technology are important elements that affect the diffusion of technology. Bullock (2004) discovered that educators' attitudes are a major enabler of technology adoption. Furthermore, the integration of technology in schools, such as GIS in geography, is a complicated issue that demands a knowledge of the motives, attitudes, and beliefs of teachers regarding the learning of that technology (Keengwe & Onchwari, 2008; Hartman, Townsend & Jackson, 2019). Teachers' attitudes, which they refer to as a humanistic influence, are critical to the successful application of technology like GIS in classrooms (Hartman, Townsend & Jackson, 2019). This is because teachers are the ones who eventually determine how learners use technology in the classroom. As such, the transition from non-utilisation of technology to the adoption and integration of technology should be managed properly. Teachers may be willing to accept change if the transition went smoothly and the process went well (Hartman, Townsend &

Jackson, 2019, p.238). In contrast, if the change is not positive, the "announcement" creates negative feelings and doubt among teachers who may want to adopt the new technology (Hartman, Townsend & Jackson, 2019, p.238). Unmanaged transitions from traditional ways of doing things to new initiatives may result in resistance and uncertainty (Kilinc, Demiral & Kartal, 2017; Reid, 2017). Furthermore, teachers' prior experiences with technology may influence their ability to successfully implement an innovation such as GIS (Reid, 2017; Demirbağ & Kılınç, 2018). According to the theory, teachers are less inclined to implement technology if the focus of the change violates their existing belief system, and hence become resistant to change. Changes that are linked to the teachers' core beliefs are more likely to be accepted and successful (Demirbağ & Kılınç, 2018). The association will make teachers more confident in the development of change and more likely to use technology (Reid, 2017).

Technology integration and diffusion can be more easily accomplished if the teachers involved are enthusiastic about a particular type of technology and believe that it will benefit their classes (Hew & Brush, 2007). This finding necessitates further research into teachers' attitudes toward and perceptions of technology. Several studies have identified barriers, such as teachers' lack of competence and knowledge, as well as their lack of prior experience, as well as their resistance to incorporating new technologies into their lessons (Scheffler & Logan,1999; Ottesen, 2006; Zhang, 2007; Paraskeva et al., 2008; Sadik, 2008; Hartman, Townsend & Jackson, 2019). Teachers who are unsure about incorporating technology into their lessons are more likely to avoid doing so (Dooley, 1999; Hartman, Townsend & Jackson, 2019). Teachers' decisions to employ new technologies in the classroom are influenced by a variety of factors, including access to resources, the quality of software and hardware, ease of use, incentives to change, support, collegiality in the school, and their dedication to professional learning (Mumtaz, 2000; Hartman, Townsend & Jackson, 2019).

Substantial research has revealed that there is a connection between attitudes and the willingness of teachers to adopt technology and in particular GIS (Demirci & Karaburun, 2009; Akinyemi, 2015; Zondi & Tarisayi, 2020; Mkhongi & Musakwa, 2020). In his study of teachers' attitudes toward GIS in Turkish high schools, Demirci (2009) discovered that teachers who had a positive attitude toward GIS was seen as a useful teaching tool for geography classes. As a result, educators who have a favourable attitude toward technology are more likely than those who have a negative attitude to use it and integrate it into their teaching (Kerski, 2003; Akinyemi, 2015; Zondi & Tarisayi, 2020). This also implies that educators' attitudes should be aligned with the goal of improving computer integration and avoiding educator resentment of ICT (Watson, 2001).

2.15 VIEWS AND PERCEPTIONS OF TEACHERS TOWARDS GIS TECHNOLOGY

Perceptions refer to the way people think about something, or the impression one has about something (Okwilagwe, 2012). On the other hand, a view (opinion) is a belief or judgement- it is what one thinks about something (Ghavifekr & Rosdy, 2015). The key difference between opinion and perception is what one thinks is always shaped by the way one sees and understand things. Therefore, a person's opinion or view is always influenced by his perception. Many people use the terms interchangeably. Teachers have had different perceptions about GIS since the advent of GIS technology in geography education. This section will consider literature that investigated the ways teachers who teach geography perceive GIS technology.

Teachers' perceptions of GIS technology

The essence of geography teaching is not limited to explaining particular geographical events and measuring, in the exams, how much of the content had been memorised; instead, the aim is to help learners understand life and all its constituents (Aydin & Kaya, 2010; Healy, Hall & Whelan, 2018). Geography education enables learners to learn about the necessity of living in groups and providing social solidarity, and the reason why social development is crucial. However, these learning goals cannot be achieved if the teachers lack knowledge, skills and necessary equipment (Aydin & Kaya, 2010; Degirmenci, 2018; Hartman, Townsend & Jackson, 2019). The teachers' views on technology, such as GIS, which Sharpe & Huynh (2015) argues offers pathways to deeper geographical understanding, is important for transmitting knowledge to learners. Research by Degirmenci (2018) in Turkey suggested that teachers do not use GIS in their geography lessons due to a lack knowledge and expertise on how to use it. Lack of knowledge on GIS use tends to affect the perceptions/opinions of teachers on the importance of GIS and its use. In order to improve the perceptions/opinions of high school teachers on GIS, geography teachers should be highly knowledgeable, trained on GIS software and on how to use it and teach it. Also, there is need to train teachers on how they can teach and transfer this knowledge and skills to the learners using the limited resources which are to their deposal (Aydin & Kaya, 2010). Also, geography teachers should be highly knowledgeable about geographical science and have the skills to transfer this knowledge and skills with suitable methods and techniques, and to use the necessary materials and technologies in their lessons (Aydin & Kaya, 2010).

Teachers' perceptions of the subject and content knowledge play a significant role in subject teaching. The perceptions of geography teachers about GIS varies and it influences the way they teach it to the learners. A study by Attia (2017) on teachers' perception on the relationship between subject specialised teaching and learner success revealed that that limited content knowledge on the subject negatively affect teachers' performance and learners' achievement. It also lowers confidence in the teacher, lower comfort level, and limited preparation time for the lesson. GIS topics were introduced recently in the geography curriculum in FET phase in South Africa and as such most of the teachers who teach geography lacked the content knowledge for GIS. Some of these teachers completed their training courses to become teachers when the GIS modules were not being taught in the colleges and universities which train teachers. A study by Mzuza and van der Westhuizen (2019) on the state of GIS in the Southern African region revealed that there are few institutes of higher education which teach GIS to learner teachers.

2.16 HUMANISTIC INFLUENCE ON TECHNOLOGY INTEGRATION

A humanistic approach is defined as one that considers the entire person. This totality of a human being encompasses the individual's ideals, beliefs, confidence, and emotions (Fedorenko, 2018). Teaching as a humanistic undertaking, teachers usually find happiness when they teach and interact with the learners they teach and when they freely share their knowledge (Azzaro, 2014). Schools need teachers who can be able to narrow the gap between human and technology (Demirci, 2008). Without the change of mind by the teacher, changing from teacher-centred approach to learner-centred instruction and learning will remain difficult. The learners of today more especially the "digital native generation" who are good at multitasking, learn more efficiently in a technology rich environment where they can be able to create their own knowledge than where the knowledge is poured on them (El Fadil, 2015; Somera, 2018). The teachers' values and beliefs and level of confidence need to be changed first because the teachers' values and beliefs tend to affect the adoption of new technologies and in the ways the technology is taught in the classes, the pedagogies of technology (Hartman, Townsend and Jackson, 2019). A positive attitude toward the use of any technology has been shown to influence the decision to use or not use the technology. Positive attitudes have a significant impact on whether technology integration is accepted or rejected (Hartman, Townsend & Jackson, 2019).

On the other hand, resistance to new technology such as GIS in high schools can be due to a number of reasons. The first factor could be that the teachers are afraid of change. In this case, not all teachers are capable of embracing change. They approach change brought by new technology with a fixed mind-set and usually give up easily when the technology becomes difficulty to use and to learn. Such teachers will be afraid of failing (Dress, 2016). A shift from teacher-centred to learner-centred, for example, is a significant shift that may be perceived as a loss of control by teachers (Hartman et al., 2019). Such teachers need more support to transit to learner-centred without such support needed the teacher might find it very difficult to change more especially if the technology is seen not to be adding any value or contribution to their traditional teaching approaches (Kilinc et al., 2017). Teachers may see it as burden to use the technology (Cheung et al., 2018). The resistance can also have emanated from education efficacy. Self-efficacy refers to one's belief in one's own ability to succeed at a given task or behavior in this context (Alenezi, 2017). Without such education efficiency in technology which brings about confidence in an individual on how to use that technology (Ertmer & Leftwich, 2010) will be absent. Teachers will continue to shun learning new technologies if they find that they are not capacitated on how to use it and if it does not serve their purpose. Computer self-efficacy (CSE) is defined as the ability to use technology and computers with confidence and knowledge (Hartman et al., 2019). Teachers who have had little or no exposure to technology in their daily lives or who have received no support at all are more likely to resist using technology (Kilinc et al., 2017). Teachers with higher CSE experience less frustration and are more likely to utilize technology more frequently in the future (Cheung, et al., 2018). Teachers will usually adopt technology if it makes their work easier for example if it makes the completion of tasks simpler (Bhatiasevi & Naglis, 2017). Teachers who lack CSE need assistance from the mentors who can be able to motivate them to build confidence. The mentors (the first adopter by Rogers) would be change agents. The agent would reassure and support you. It would necessitate a shift not only in a teacher's pedagogical and technological knowledge, but also in their sense of self-efficacy, pedagogical beliefs, subject knowledge, and school culture (Ertmer & Leftwich, 2010; Reid, 2014). The mentors can provide just-in-time assistance and are ready to assist teachers in increasing their use of technology such as GIS (Hartman et al., 2019)

2.17 CONCLUSION

This section reviewed literature relating to the topic of this study. The literature review showed that teachers employ two broad pedagogical approaches (teacher-centred and learner-centred pedagogical approaches) to teaching. Under teacher-centred pedagogical approaches, teachers' use teaching methods such as questioning and explaining, and under learner-centred pedagogical approaches, teachers use demonstrations, fieldwork/study and projects. The choice of pedagogical approach depends on teachers' initiative, the pedagogical content knowledge (PCK) of a teacher, and the resources available at the school.

The chapter also reviewed literature reporting on the way various countries have included GIS in their curricula. The review noted that the problems associated with the adoption of new technology vary, according to the development level of the country. Finally, this chapter reviewed theories of information communication technology and GIS. The review led to the adoption of Rogers' theory of DOI, and the TAM as the theoretical framing of this research.

The adoption of GIS technology takes place in stages, as Rogers suggests, and the way teachers adopt it depends on a number of factors, which were outlined in this chapter. The perceived usefulness of the technology was an important factor. If a teacher finds the technology useful, he or she will be willing to adopt and incorporate it into their classroom instruction. Also, the other factors include the ease of the technology to use. The theories: DOI and TAM suggested that for the technology to be easily adopted and integrated, it should be perceived easy to use and implement. These factors in the theories help to shape the attitude of the person who may want to adopt the technology. The literature indicates that once the attitude of the potential user is positively influenced, this will change the behaviour of the person towards the adoption of the technology.

The chapter also explored perceptions and attitudes of teacher's adoption and integration of technology. In the literature reviewed it was revealed that teachers' perceptions and attitudes determined whether they adopt a new technology or not. It was reported that knowledge and experience of technology which can be acquired through training can also change the way people perceive and embrace new technology such as GIS in the curriculum as a section to be taught or in its use in Geography lessons on other topics.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

The previous chapter discussed the literature reviewed in this study. The main ideas and theories that form the foundation of this study were discussed and the rationale why they were chosen was discussed.

3.1 INTRODUCTION

The main trust of this current chapter is to explain and describe the technique and methods that were employed to perform this research. A researcher must always carefully establish a research plan to answer the research questions or research objectives (Blaikie & Priest, 2019). The strategy serves to provides a methodological framework within which data is collected, processed and analysed.

Given this backdrop, the chapter discusses the research philosophies and paradigms that are used in this research. Upon outlining and discussing the paradigms, this chapter discusses mixed method research (MMR) which was used. The chapter goes on to outline the sampling (selection of participants) techniques, ethics and the data collection processes. Also, in this chapter, the issues of rigor namely validity and reliability are discussed. The chapter provides the necessary procedures on how this research was designed and executed. Furthermore, the research methods developed for this study enabled me to investigate the pedagogical approaches used in the teaching of GIS in high schools in South Africa's Northern Cape province.

This chapter is divided into seven sections. It starts by discussing the research philosophy and paradigm. Then, I place the study in the realm of mixed methods research (MMR). The second section describes the geography study site and provides a brief background on educational issues. The third section outlines the population and sample used for the MMR approach, while the fourth section describes the data collection methods used in this study. Since the study adopted an MMR approach, the questionnaire which was used, interviews and lesson observations are explained and justified for their use in this research.

The fifth section discusses the data analysis procedures. The sixth section reports on validity and reliability issues of the study, using the lens of a mixed approach. The chapter ends with a description of the ethical considerations that were necessary for this study.

3.2 RESEARCH OBJECTIVES AND RESEARCH QUESTIONS

This study aimed to explore GIS diffusion hence, it unfolded through exploring the teaching of GIS (the geography FET curriculum) in high schools in the Northern Cape province of South Africa. It, further, sought to explore the pedagogical approaches currently used by teachers for teaching GIS in geography in high schools in South Africa. As a result, four objectives were set to be achieved in this study; they are explained in the following subsections.

TO EXAMINE TEACHERS' ATTITUDES TOWARDS THE TEACHING OF GIS IN GEOGRAPHY IN THE FET PHASE

This objective aimed to examine teachers' attitudes towards the teaching of GIS in geography in the FET phase in the Northern Cape province. I was interested in exploring and understanding the attitudes of the geography teachers, since the diffusion of innovation literature asserts that a teacher's attitude determines if an innovation will be adopted in the class. If the teacher does not have a positive attitude, he/she will not put much effort into adopting an innovation and this may result in the learners lagging behind in knowing how to use certain technologies. In this case, if the geography teachers are not interested in GIS or see no value in GIS, it will be very difficult for the learners to gain the skills needed (in the section on GIS in the CAPS) from their teachers. I wanted to gain insight into this, teachers' views and their approaches.

TO EXAMINE TEACHERS' VIEWS ABOUT GIS TEACHING IN GEOGRAPHY IN THE FET PHASE.

This objective seeks to examine the views of teachers who teach GIS, what are their opinions concerning the inclusion of GIS as a topic in the geography curriculum in the FET phase.

TO EXPLORE THE PEDAGOGICAL APPROACHES USED TO TEACH GIS

The intention was to explore the pedagogical approaches used by geography teachers to teach the section: GIS. The objective also sought to probe whether these pedagogical approaches are adequate to help the learners to understand the key concepts in the section: GIS.

TO EXAMINE THE REASONS WHY GEOGRAPHY TEACHERS, USE THESE PARTICULAR PEDAGOGICAL APPROACHES TO TEACH GIS

This goal sought to elucidate the possible reasons for the teachers' use of specific pedagogical approaches (teaching methods and strategies). The following were the research questions that informed the aforementioned objectives:

- What are teachers' attitudes towards GIS in geography in the FET curriculum?
- What are the teachers' views about GIS in geography in the FET curriculum?
- What are the pedagogical approaches used to teach GIS?
- Why do teachers use these pedagogical approaches to teach GIS?

3.3 RESEARCH PARADIGM

Educational research is guided by several views and assumptions (Cohen, Manion & Morrison, 2018). A paradigm is defined as a set of beliefs and assumptions that govern how people ask questions and what they believe to be true (Schroeder & Schmidt, 2013). Since this research adopted a mixed methods research, it does not strictly align with either the world view of interpretivism or positivism only, rather a pragmatist approach is used. Interpretivism as a world view states that reality is constructed and "assumes that multiple realities are socially constructed through individual and collective perceptions or views of the same situation" (McMillan & Schumacher, 2014, p.20). On the other hand, positivism assumes that there are "stable, social facts with a single reality separated from the feelings and beliefs of individuals" (McMillan & Schumacher, 2014, p.20). Pragmatism is not bound by a single philosophy or reality (Creswell & Poth, 2018). Researchers are free to use whatever methods they want to achieve their objectives. Pragmatists do not see the world as an absolute unity; rather, researchers look at a variety of approaches to data collection and analysis in order to understand reality rather than adhering to a single approach (Creswell & Poth, 2018). In some cases, a pragmatic approach combined quantitative and qualitative approach in one methodology. Pragmatist researchers consider the "what" and "how" of research in terms of its intended outcomes—where they want to go with the research (Creswell & Poth, 2018, p.27). Some scholars suggested that MMR operates in a transformative paradigm (Cohen, Manion & Morrison, 2018), and this resonates very well with this study because it aimed at understanding the pedagogical approaches used by the geography teachers to teach GIS and their views and attitudes about the inclusion of GIS in geography curriculum in high schools in Northern Cape province. In this study I accessed knowledge from the teachers through interactions with them (Alvermann & Mallozzi, 2010; De Vos, Strydom, Fouche & Delport, 2011) in high schools in Northern Cape province. I used a combination of questionnaires, interviews and lesson observations and this enabled me to gain epistemological insights into how and why the teachers are teaching GIS topics in the way they are teaching it. This notion is supported by Wisker (2008) and Blumberg, Cooper & Schindler (2011), who argue that the social world is constructed and given meaning by people and in this case by the teachers. Also, the teachers' attitudes and views on the different topics of GIS they were teaching during the course of the research, was evident. Finally, I wanted to explore if there are correlations between certain variables which would explain their teaching of GIS, which tilted the study towards positivism. The details of these aspects are discussed below.

Pragmatism is a philosophy that "claims to bridge the gap between older approaches' scientific method and structuralist orientation and newer approaches' naturalistic methods and freewheeling orientation" (Kaushik & Walsh, 2019, p. 2). It's a problem-solving philosophy that believes the best research methods are those that help people understand and answer their research questions (Tashakkori & Teddlie, 2010; Kaushik & Walsh, 2019). Pragmatism focuses on the outcomes of study and the research questions rather than the techniques (Maxcy 2003; Teddlie & Tashakkori 2009). The pragmatist scholars dispute the notion that social science inquiry can only arrive at the truth using a single scientific technique. They believed that individuals could understand the truth if they employ a variety of scientific methodologies (Maxcy, 2003).

As a paradigm, pragmatism emphasizes meaning and fosters an understanding of participants' actions in their context (Creswell, 2013; Creswell & Poth, 2018). It is concerned with a descriptive analysis of participants' perceptions of their lived experiences in the context of history (Creswell, 2013). I aimed to understand the pedagogical approaches (actions) geography teachers use when they teach GIS. The study centred on interpreting and comprehending participants' classroom experiences, which is consistent with pragmatist epistemology (Pansiri, 2005; Kaushik & Walsh, 2019; Mertens, 2014). Pragmatist researchers think that reality is made up of people's subjective views of the outside world and that it cannot be explained by a single approach; as a result, researchers may use numerous methods to comprehend reality. Human actions, according to pragmatist philosophy, are not free of their past experiences and the beliefs that arose as a result of those experiences (Kaushik & Walsh, 2019). Human opinions are thus primarily connected to action. According to Kaushik and Walsh (2019), the main argument of pragmatist philosophy is that the meaning of human actions and beliefs is found in their consequences (p.3). Humans are not governed by outside forces; they are capable of determining their own experiences through their actions and intelligence. Under pragmatism, reality is not static; it is constantly changing as a result of actions—action is the means by which existence can be altered (Maxcy, 2003; Goldkuhl, 2012). Pragmatist researchers derive their constructs from the field by conducting an in-depth investigation of the phenomenon of interest at the research site. Through lesson observations and interacting with the geography teachers who were teaching GIS I came to experience and understand (environment) their way of doing things. “Actions cannot be separated from the situations and contexts in which they occur” (Mertens, 2014, p.26). Finally, pragmatism draws its conclusions from the variable changes in a naturalistic environment. For instance, in this research, geography teachers were observed delivering GIS lessons and learners were observed learning GIS in a classroom context.

According to Kaushik and Walsh (2019, p. 3), knowledge and reality are dependent on socially constructed ideas and habits, according to pragmatic philosophy. Knowledge is socially built in this environment, although some aspects of that social construction better fit individuals' experiences than others.

3.4 QUALITATIVE METHODOLOGY

Qualitative methodology has value in a paradigm that seeks to understand; a qualitative methodology employs methods that involve the generation of textual or verbal data and graphic data (data that cannot be quantified) (Bussetto, Wick & Gumbinger, 2020, p.3). Data is not seen as something “out there”, to be collected or captured, but as something created through a social process (Bussetto et al., 2020, p.5). In this research the unit of analysis was geography teachers in secondary schools in Frances Baard District. A qualitative method is usually used when depth is required and when some of the questions cannot be able to be answered by a questionnaire instrument. For example, in this research, the questionnaire could not be able to answer my critical questions on attitude and views of the teachers. These questions required explanation and greater depth especially when I observed the teachers teaching the GIS topics and when I interviewed the teachers (pre and post lesson observation). The lesson observations and the interviews with the teachers assisted me to unearth rich data which would not have been revealed by a questionnaire. With the interviews and lesson observations I had the opportunity to probe further in order to extract more detailed data from the teachers. Also, with the lesson observations I could see the teacher’s facial expression and note the classroom set up, the resources available and the learners’ responses and behaviour during the lesson (Guba & Lincoln, 1994; Lincoln & Guba, 2000; Shulman, 2000). According to Mouton, (2007), a qualitative methodology allows the researcher to be close to the participants and thus develop a better understanding of what they are experiencing and doing on a daily basis. In this study, it was evident how geography teachers delivered GIS lessons in their respective contexts and with the resources at their disposal.

Qualitative research methodology was relevant for this study for three main reasons. First, it is deemed to be more fluid and flexible than quantitative research, in that it accentuates discovering novel or unanticipated findings, and it allows the researcher to adjust research plans in response to such unexpected incidences (Bryman & Teevan, 2005) – an important consideration for this study, as there have been few studies on GIS in high schools in South

Africa and this study will allow the researcher to probe aspects of relevance to individual teachers to better understand the phenomenon. Second, qualitative research produces results and theories that are understandable and empirically sound to educators and others interested in the phenomenon being studied (McMillan & Schumacher, 2014; Cohen, Manion & Morrison, 2018). Finally, qualitative research is best suited for studies that aim to improve prevailing practice rather than determining program outcomes. Because the goal of this study was to gain a comprehensive understanding of the pedagogical approaches used by teachers teaching GIS in high schools in the study area, qualitative research was relevant in this regard (Cohen, Manion & Morrison (2018).

3.5 QUANTITATIVE METHODOLOGY

Since this research adopted a mixed methodology design, it is prudent to discuss quantitative methodology. Quantitative methodology is located within the positivist paradigm. In its simplest terms, a quantitative approach deals with the statistical analysis and numerical data, and it provides quantitative information (Ravitch & Carl, 2021). Quantitative research entails gathering quantitative data in the form of numbers while attempting to eliminate bias from the researcher. A questionnaire was used in this study to collect important information from geography teachers who were not available to be interviewed or observed while teaching GIS lessons. As such it was complementary to gathering qualitative data and it thus added to the data gathered qualitatively for the study. In this study quantitative data was collected first and the quantitative data findings were used to create the interview questions which were used in the qualitative data collect to further understands deep understanding about the questions which were researched in this study.

3.6 CONTEXT OF THE STUDY

The research was done in South Africa's Northern Cape Province in Frances Baard. The Province is divided into five districts. A district, also known as a Category C municipality, is a municipality that performs some local government functions for a district. The district, in turn, is made up of a number of local municipalities with which it shares local government functions. In total, the province had approximately 684 teachers and 20 268 learners (Statistics South Africa (STATS SA), 2016). Table 3.1 summarizes the number of secondary and primary schools in the province of the Northern Cape.

Table 3.1: Summary of the number of schools, leaners and teachers in the Northern Cape Province

			Total		Average per school	
Municipality	Phase	Schools	Learners	Educators	Learners	Educators
Frances Baard District Municipality	Primary	43	37 321	10 86	868	25
	Secondary	22	20 268	684	921	31
Kgalagadi District Municipality	Primary	42	26 127	738	622	18
	Secondary	22	13 460	515	612	23
Namakwa District Municipality	Primary	11	6 763	177	615	16
	Secondary	4	2 152	68	538	17
Pixley ka Seme District Municipality	Primary	23	17 848	464	776	20
	Secondary	15	10 039	348	669	23
Siyanda District Municipality	Primary	19	15 115	415	796	22
	Secondary	10	10 983	357	1 098	36
Total	Primary	138	103 174	2 280	748	21
	Secondary	73	56 902	1 971	779	27

Source: (Statistics South Africa (STATS SA), (2016).

From these five districts, I undertook my study in Frances Baard District. Frances Baard District was selected due to it being near my working environment and also it offers a variety of high schools, which include township schools, peri-urban schools, rural schools, private schools and former C model schools. This diversity enabled me to understand how GIS topics are taught in the different high schools since these schools are resourced differently. Their contextual difference gave me a picture on how GIS is being taught in these schools.

Frances Baard District comprises five local municipalities namely, Sol Paatje, Phokwane, Dikagatlong, Magareng and Diamond Fields. The high schools that were involved in this in this case study were purposefully sampled from Frances Baard District Municipality (see Figure 3.1). The study area includes the diamond mining city of Kimberley. The Frances Baard District Municipality covers about 3 145 km² and consists of a total number of 38 (see Table 3.2) high schools that offer geography subject. In this study, 10 geography teachers (those teaching in the FET phase where GIS is a topic) were purposefully chosen from 10 high schools in the Frances Baard District on the basis of their interest to be part of the study. The schools comprised two rural high schools, three former Model C high schools, one private high school and four township high schools. I used this diverse selection to ensure that there was representation of all the types of high schools found in the study area. It was at these 10 high schools that I conducted interviews (pre and post) and lesson observations.

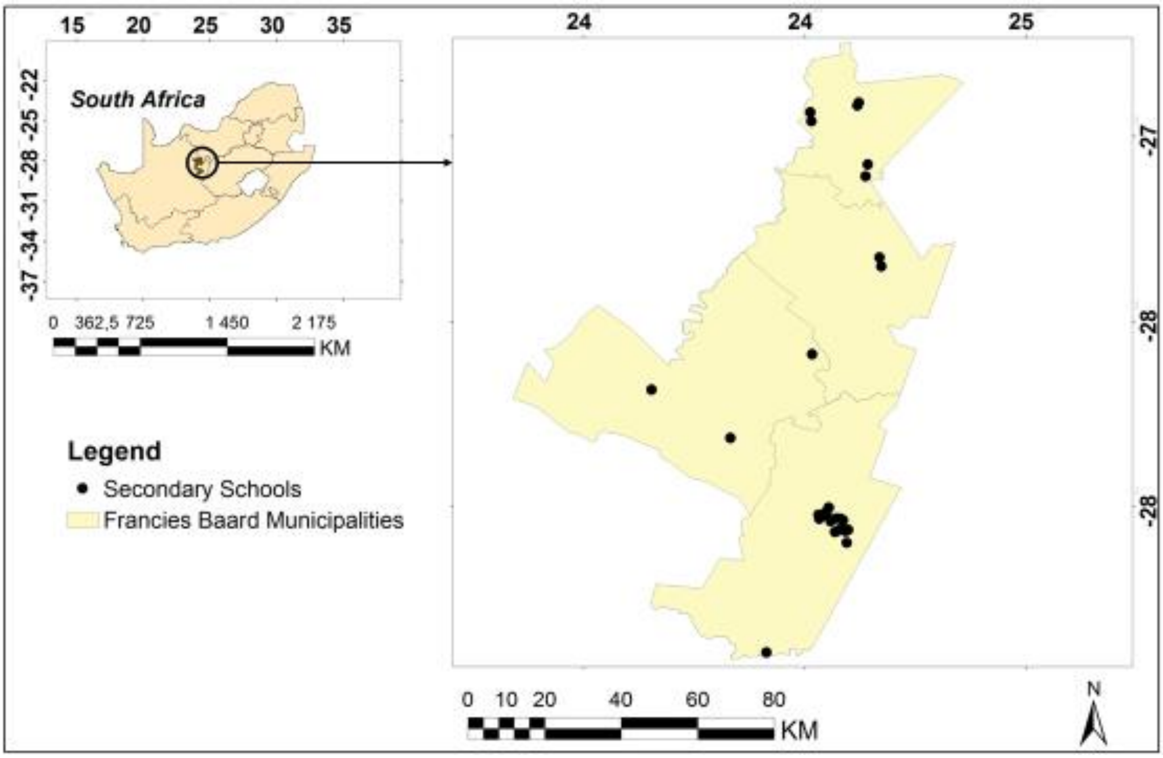


Figure 3.1: Frances Baard District map: distribution of secondary schools

The average teacher learner ratio in the Frances Baard District, where most of the high schools were purposively sampled, is 1:30. The ratio is slightly higher than the provincial average of 1:28.9. The Frances Baard District senior national certificate pass rate has been improving slowly since 2014. The overall general pass rate in geography was 76.2% in 2012, 77.4% in 2013 and 67.8% in 2014. The decline in pass rate in 2014 was followed by improvement in 2015 (78.5%), and an 80% pass in 2016 (Statistics South Africa (STATS SA), 2016). Generally, the province has very few schools that are highly ranked in the country. Despite this, it has received consecutive outstanding matriculation pass rates from some schools, while others continue to have poor pass rates. Furthermore, the number of schools in the province that offer geography is growing (DoE, 2014). Appendix (F) summarizes the number of schools that offer geography in the Frances Baard district of the Northern Cape province.

3.7 RESEARCH RIGOUR

The study was cognisant of the importance of research rigour using numerous data gathering tools. Triangulation in the study entailed using multiple data generation methods in one study to ensure that the results were confirmed (Saunders et al., 2018; Yeasmin & Rahman, 2012; Creswell & Plano Clark, 2018). I adopted a mixed method design with a dual-phase approach to primary data collection – quantitative (using a questionnaire survey) and qualitative (using in-depth interviews and lesson observations).

3.8 CASE STUDY DESIGN

A case study is method that is used by a researcher to closely scrutinize data in a more precise way (Lang, Damous & Lewis, 2017). This definition resonates well with the selection of a few high schools in the Northern Cape province for this study, because a case study is usually centred on a small geographical area or a small number of people as research participants. A qualitative case study design enables researchers to investigate a phenomenon in its context while collecting data from various sources (Baxter & Jack, 2008). This guarantees that the subject is examined via a variety of perspectives, providing for a better understanding of the phenomenon's many dimensions. A case study is defined by McMillan and Schumacher (2014, p. 370) as "an in-depth analysis of a single entity." According to Leedy and Ormrod (2016, p.36), a case study is "a specific individual, program, or event that is studied in depth for a defined period of time." It's appropriate for learning more about a situation that's less well-known or understood, such as the teaching of GIS, a topic that was recently included to the geography curriculum.

A case study design, according to Yin (2013), should be considered when: (a) the study's focus is to answer "how" and "why" questions; (b) the researcher cannot control the participants' conduct; (c) the researcher wishes to include the contextual factors because he/she thinks they are important to the phenomenon under investigation; or (d) the lines between phenomenon and context are unclear. This study used a case study design to investigate why educators use specific pedagogical approaches (loosely defined as teaching methods) to teach GIS. I chose a case study because I was curious about educators' decisions about the best ways to teach GIS topics.

However, a case study could not be considered without bearing in mind the context and, more specifically, the school and classroom settings that influence teachers regarding the methodology they use to teach GIS. It was in these backgrounds that teachers' decision-making skills were developed and utilised. It would have been impossible for me to gain an understanding of teachers' decision-making in selecting appropriate pedagogies for teaching GIS without taking into account the context in which it was taking place.

3.9 DATA GENERATION

Data was generated sequentially. An explanatory sequential design gathers quantitative data first, followed by qualitative data to explain quantitative outcomes (Creswell & Plano Clark, 2018).

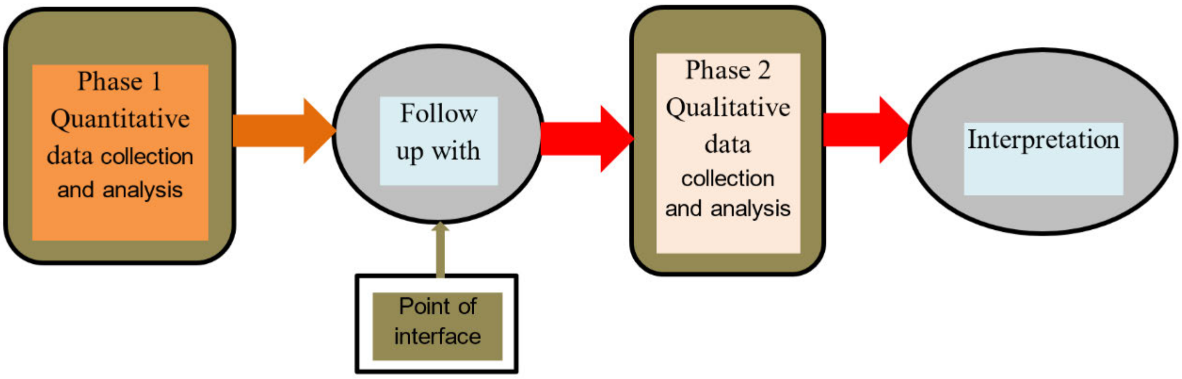


Figure 3.2: Explanatory sequential design

Source: Creswell & Plano Clark (2018)

The rationale for this approach was that quantitative data and results would provide a broad picture of the research problem, and that further analysis, specifically qualitative data generation, would be needed to refine, extend, or explain the broad picture developed from quantitative data collection (Subedi, 2016). As a result, the design was divided into two distinct phases: The generation and analysis of quantitative data is followed by the generation and analysis of qualitative data. The quantitative (numerical) data was collected and analysed first in this design. Second, qualitative (text) data was collected and analysed (Figure 3.2). This approach, according to Creswell and Plano Clark (2018), begins with gathering and analysing quantitative data as Step 1. The results of the first step were used as variables to create structured interview questions for the second phase, allowing for a clear expression of a deep understanding of the researched problem. This allowed the researcher to gain a thorough understanding of the variables addressed by the quantitative survey. In this research, the pedagogical approaches used by teachers to teach GIS, as well as the attitudes of the teachers towards GIS were investigated. Thus, I interviewed and observed the teachers teaching GIS in the classroom, to get an in-depth understanding of the pedagogical approaches they used (Creswell & Plano Clark, 2018). This approach enabled me to understand the interplay between the two datasets.

A model of the instrument-development variant of the explanatory mixed method research design is depicted in Figure 3.3. The model shows that quantitative and qualitative data were collected separately using questionnaires, interviews and lesson observations respectively and then integrated in the findings to provide understanding.

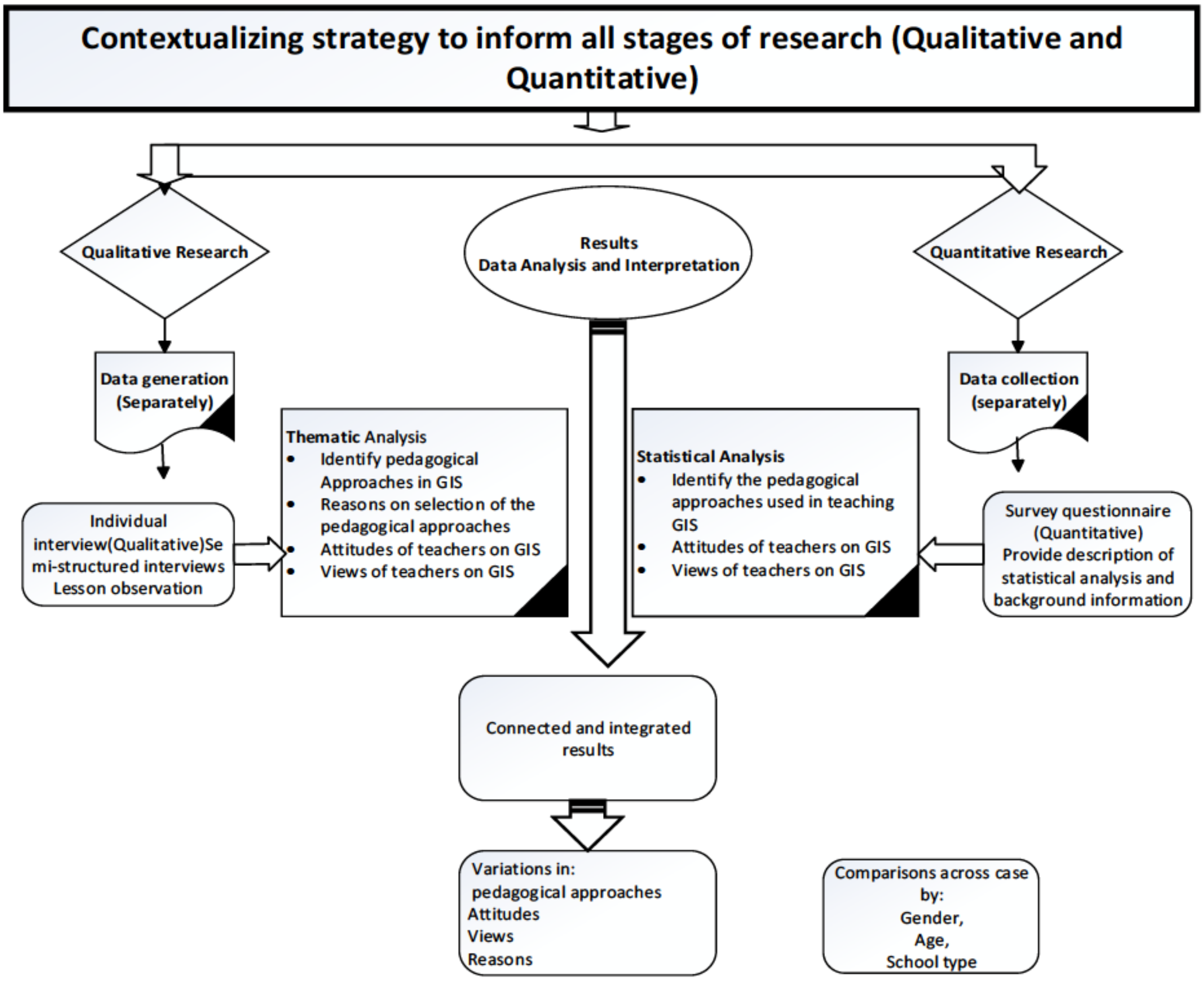


Figure 3.3: Data generation process

Source: Own model crafted

The interviews (pre- and post-lesson observation) were done with teachers who teach geography at high schools. These interviews sought to establish the pedagogical approaches used by teachers to teach GIS aspects. The interviews and lesson observations also sought to identify the perceptions and attitudes of teachers towards GIS. The pedagogical approaches and attitudes of the teachers were evaluated during lesson observation, when the teachers were implementing their teaching approaches in the classroom. The interview collected data that were analysed thematically.

A number of questions that seek to address issues relating to teachers' pedagogical approaches, attitudes and the views of teachers towards GIS, were also asked. The data that were collected/generated were sorted, analysed statistically and qualitatively and then presented in narratives, tables, graphs and pie charts. The results of the qualitative and quantitative research approaches were connected and integrated in Chapters 4 and 5.

3.10 SAMPLING DESIGN

The sampling design is an important component of any research design because it affects the quality of data in the study (Bryman & Bell, 2007). The sampling design comprised five sequential stages and, as noted by Malhotra (2010), the steps are interwoven and executed sequentially in the study. The sampling design for this study is shown in Figure 3.4 and were followed in sequential steps.

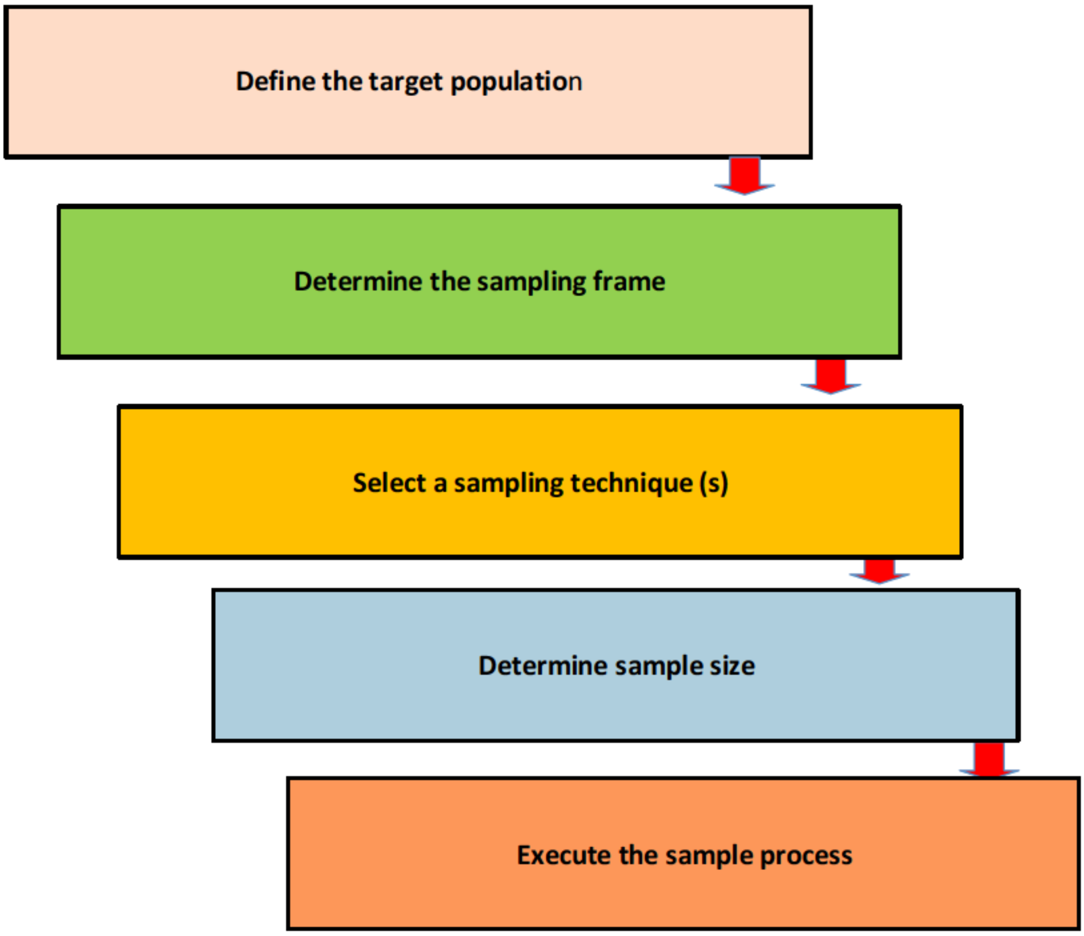


Figure 3.4: The sampling design process

Source: Malhotra (2010, p. 372)

3.11 TARGET POPULATION

The study population refers to participants who are suitable for a given study (Malhotra, 2010; Adams & Lawrence, 2019). According to Malhotra (2010), it is important to understand the planned population units of investigation as well as the geographical location of the participants. A researcher must have a thorough understanding of the characteristics of the target population in order to reduce research costs and improve response rates and data quality (Saunders et al., 2012).

3.12 SAMPLE SIZE

The number of elements included in the sample is referred to as the sample size. The population for a given study is represented by the sample. (Silverman, 2021). The sample was made up of 10 geography teachers, who were interviewed and had their lessons observed, and 50 geography teachers, who participated by completing a questionnaire survey. All the participants were drawn from schools in the Northern Cape province of South Africa. The participants were randomly selected from schools that were willing to participate in this research. Since the research adopted a mixed methods approach, the sample size was divided into two sections for data validity and reliability. The teachers who participated in the qualitative research were not the same as the ones who participated in the quantitative research. This distinction was made to get an in-depth understanding of the concepts under investigation and to avoid bias in the results of this research. For the interviews and lesson observations, 15 high school geography teachers were the target population, and 70 geography teachers were the target population for the questionnaire survey. Table 3.2 summarises the breakdown of the participants.

3.13 SAMPLING TECHNIQUES

According to Saunders et al (2012), sampling is a technique used to select a more appropriate and substantial amount of data for a specific exploratory study. There are two types of sampling techniques: probability and non-probability sampling. The probability sampling technique is used to select research subjects, and everyone in the target population has the same chance of being chosen (Quinlan, 2011).

Table 3.2: Research sample size (participants)

Research activity	Participants	Target number of participants	Responses	Responses %	Phase of primary data collection
In-depth interviews Lesson observation	Geography teachers	15	10	66.6	Phase 1
Questionnaire survey	Geography teachers	70	50	71.4	Phase 2
Total		85	60	70.5	

Non-probability sampling is a technique for selecting participants from a population in which the probability of anyone being chosen from the population is unknown (Zikmund et al., 2010, p.256). Purposive sampling (nonprobability sampling) was used in this study to identify geography teachers for in-depth interviews and lesson observations, and random sampling was used for the questionnaire survey. Purposive sampling was used for qualitative data generation because it is reliable and helps the researcher selected participants who were present and willing to participate when the researcher entered the sample site, and it served the purpose of the study (Clark-Carter, 2019). Purposive sampling was also used because it covers other cases that had not been covered by the quantitative component, and to increase the transferability of the findings to other cases (Teddlie & Yu, 2007; Yin, 2016).

The questionnaire for the quantitative data was distributed randomly to geography teachers who teach geography in the Northern Cape province. Some of the questionnaires were distributed to teachers when they attended a workshop on matric results at the Elizabeth Conradie High School in Kimberley on 26 February 2016, while some questionnaires were sent to the selected schools which did not attend the workshop.

3.14 POPULATION AND SAMPLING

Population is a group of people, things or trials from which research wishes to create interpretation (Banerjee & Chaudhury, 2010). In research, it is not always possible or convenient to research every person in the population. As a result, the researcher has to select a small population that will represent the target population. In this study, the target population comprised geography teachers who teach geography in the FET phase, that is, Grades 10, 11 and 12. A sample is, therefore, a subset of the population, from which the researcher collects and analyses data to make inferences (Banerjee & Chaudhury, 2010). A sample constitutes “the elements of the population considered for actual inclusion in the study”

(Arkava & Lane, 1983, p. 27). Furthermore, according to Marshall and Rossman (2015), a suitable sample size for a qualitative study is one that provides adequate answers to the research questions. The sample included 50 high school educators who took part in the study by filling out a single questionnaire, as well as 10 teachers who were interviewed and observed while teaching GIS topics in Northern Cape high schools. With this sample, data saturation was achieved.

There are two major classes of sampling procedures. These are probability sampling (random sampling), which is based on randomisation, and non-probability sampling (purposive sampling), which is done without randomisation (Strydom & Venter, 2002). Probability sampling methods were deemed inappropriate for this study, for various reasons. Firstly, “for a true random sample to be selected the characteristics under study of the whole population should be known; this is rarely possible in a complex qualitative study” (Marshall, 1996, p. 523). Thus, it was difficult to know the characteristics of all the educators in the district and, therefore, a purposive sample of 10 educators was used. Secondly, random population sampling is used to create a representative population that can be used to answer the research questions (McMillan & Schumacher, 2014; Cohen, Manion & Morrison, 2018). Finally, "qualitative researchers recognize that some informants are 'richer' than others, and that these people are more likely to provide the researcher with insight and understanding" than other members of the population (Marshall, 1996, p. 523). Furthermore, some people were hesitant to take part in the study. This means that the researcher must select a sufficient sample to ensure the research's validity and reliability.

The non-probability purposive sampling technique, also known as "judgment sampling," was used in this study (Abrahams, 2011). The most common sampling technique is purposeful sampling, in which "the researcher actively selects the most productive sample to answer the research question" (Marshall, 1996, p. 523).

The purposive sampling technique used in this study is similar to stratified purposive sampling, which involves stratifying the target population with the goal of discovering elements that are similar or different across the target population (Tashakkori & Teddlie, 2010). In this case, the researcher used a sample of 10 schools and 10 FET phase Geography educators to collect qualitative data. The interviews conducted at these 10 schools were augmented by a questionnaire survey, in which 50 teachers participated. The 50 participants were drawn from grade 10-12 (FET phase) geography teachers. This was done to elicit data from these teachers because GIS is only taught in these grades in high schools.

Even though the sampling logic in qualitative research differs from that in quantitative research, sample size, representativeness, and other fundamental quantitative concerns remain significant. (Adams & Lawrence, 2019; Clark-Carter, 2019; Ravitch & Carl, 2021).

The sample for this study was influenced by three different factors. To begin, the sample was determined by the analysis techniques to be used, which were primarily qualitative. Second, because some people may be reluctant to participate in the research, there was a possibility of a smaller number of units of analysis from which usable data could be derived than the number originally proposed (Rooney & Evans, 2019; Adams & Lawrence, 2019; Ravitch & Carl, 2021). Third, the size was determined by the resources available to conduct this research. Section 3.13 will look at the sample sizes for each group in the study.

3.15 DATA GENERATION METHOD

A questionnaire, in-depth interviews, and lesson observations were used to collect primary data. Both the questionnaire and in-depth interviews (pre and post) and lesson observation were conducted with geography teachers who teach Grades 10-12. Doing so helped me to obtain first-hand information from the participants (Goldkuhl, 2019). A questionnaire survey was chosen because it is a good strategy for collecting data in an exploratory research project and lets the researcher to obtain data from a larger number of people than other methods (Clark-Carter, 2019).

This research used two methodologies to collect data from geography teachers in the study area. The objective was to determine the level of new technology use in GIS teaching in high schools found in Frances Baard District in the Northern Cape province. The schools were made up of urban (township) and rural schools and are spread over the district. It was challenging to travel the length and breadth of the Frances Baard District to interview the teachers and do lesson observations. As a result, I could not visit all the secondary schools that teach geography in Frances Baard District. I purposively selected 10 school where I interviewed and carried out lesson/classroom observations. I used interviews and lesson observations to augment the data gathered from the questionnaire. The questionnaire was given to the teachers who could not be reached for interviews and lesson observations. The interview questions focused on issues that could not be addressed by the questionnaire survey. It gave me the opportunity to ask the teacher for clarity and deep understanding, for instance, asking the teacher why he/she chose to use certain teaching method instead of another. The interviews and lesson observations were also used to gain a deep understanding of the pedagogical approaches used by the teachers, and their attitudes about teaching GIS. This study drew information from a diversity of sources, including questionnaires, interviews (pre and post), and lesson observations. In order to establish the feasibility of the study and to follow gatekeepers' procedures, the researcher first sought permission from the Northern Cape Provincial Department of Education based in Kimberley in August 2014, which granted permission, with some conditions (see Appendix F).

After obtaining permission from the education department, the researcher visited schools to seek permission from principals and subject teachers to carry out the research. This permission gave the researcher access to schools, geography teachers, principals and geography subject advisors. Some geography teachers were not willing to be interviewed and to have their lessons observed by the researcher and they were thus excluded from the research. Questionnaires, interviews and lesson observations were the main methods used to collect data in this research.

I commenced collecting data by distributing the questionnaire. I reasoned that the questionnaire would illuminate the geography teachers' actions and activities, which would inform my questions for the interviews with them and guide me when I observed them during the lesson observations (Ravitch & Carl, 2021). In the second phase, I generated data through semi-structured interviews and lesson observations. During the interviews (post and pre-lesson observations), I listened as the geography teachers responding to the questions posed, and during the lesson observation I jotted down teachers' actions and learners' activities. Through the interviews, I was able to identify gaps in geography teachers' knowledge of GIS, as well as the strategies they used to learn about GIS on their own, despite the fact that most of the teachers were still struggling to understand GIS concepts and how best to teach them. Throughout each phase of data collection, I was conscious of not intruding into the participants' classrooms without the consent of the teacher, so I took great care to be sensitive and thoughtful towards the participants by avoiding explaining some of the concepts of GIS, especially when I saw the teacher incorrectly -teaching, and to avoid eye contact with the misbehaving learners. I wanted the lesson to be as normal as possible without my presence altering the normal rapport between the teacher and learners (Adams & Lawrence, 2019; Ndihokubwayo, Uwamahoro, & Ndayambaje, 2021). In this way I aimed for authenticity and credibility results. A summary of the research methods used is presented in Table 3.3.

Table 3.3: Summary of research methods

Method of data collection	Type	Document	Research question answered
Questionnaire	Individual answer the question	- Questionnaire instrument - Data analysed using SPSS and Fisher's exact test, and Kruskal-Wallis	- What are the pedagogical approaches used to teach GIS?
Semi-structured interviews	Individual interviews	- Audio recordings - Field notes	- What are the pedagogical approaches used to teach GIS? - Why do teachers use these pedagogical approaches to teach GIS? - What are teachers' attitudes towards GIS in geography in the FET curriculum? - What are the teachers' views about GIS in geography in the FET curriculum?
Lesson observation	Non-participants	- Audio recordings - Field notes	- What are the pedagogical approaches used to teach GIS? - Why do teachers use these pedagogical approaches to teach GIS? - What are teachers' attitudes towards GIS in geography in the FET curriculum? - What are the teachers' views about GIS in geography in the FET curriculum?

The procedures and justification for each method will be outlined in the following subsections.

Table 3.3 lists the research questions I wished to answer in this research. The table contains the list of the research questions, reasons for collecting the data, research strategy/strategies used, and the source of data collection

Table 3.4: Research questions asked, and research strategies used

Research questions	Reason for data being collected	Research strategy	Data source	No. of sources	Site of data source
What are teachers' attitudes towards GIS in geography in the FET curriculum?	Interview the teacher (pre-observation) and observe lesson. This will help to understand the attitudes of the teachers and learners and their views about GIS in geography.	Semi-structured interview Lesson observation Questionnaires	Geography teachers	10 50	High schools in the Northern Cape province
What are teachers' views about GIS in geography in the FET curriculum?	Lesson observation and post-observation interview. This will help to identify the pedagogies teachers use to teach the GIS topics	Semi-structured interview Lesson observation Questionnaires	Geography teachers	10 50	High schools in the Northern Cape province
What are the pedagogical approaches used to teach GIS?	Lesson observation and post-observation interview. This will help to identify the pedagogies teachers use to teach the GIS topics	Semi- structured interviews Questionnaires	Geography teachers	10 50	High schools in the Northern Cape province
Why do teachers use these pedagogical approaches to teach GIS?	Pre-observation interview and lesson observation. This will help to identify the methodologies teachers use when teaching GIS topics, and why they do not use other methods.	Semi-structured interview Lesson observation Questionnaires	Geography teachers	10 50	High schools in the Northern Cape province

3.15.1 TEACHERS' INTERVIEWS

Teacher interviews were conducted to determine their attitudes, views towards GIS and the pedagogical approaches they used when teaching GIS in high schools (secondary schools). In order to determine the pedagogical approaches used to teach GIS in the geography curriculum, teacher interviews were conducted in Northern Cape province in schools in the Frances Baard District.

Semi-structured interviews

In this study, semi-structured interviews were used. Semi-structred interviews are more flexible than structured interviews which are based on fixed items, precategorised responses that ask identical questions to everyone (Adams & Lawrence, 2019; Ravitch & Carl, 2021). The use of probes and follow-up questions is limited to those on the instrument in order to achieve uniformity across interviews (Ravitch & Carl, 2021). I prepared a base set of questions I wanted to ask the teachers for consistency purposes. The interview guide covered GIS-related aspects that are taught in Grades 10, 11 and 12. The aspects covered by the questions include the elements of GIS that are taught, pedagogical approaches used, reasons for choosing certain pedagogical approaches, knowledge about GIS, feelings about the inclusion of GIS in the geography curriculum, implementation of GIS in the class, experiences of teaching GIS at the school, challenges teachers face in teaching GIS, training in GIS, teachers' beliefs about and experiences with GIS, and the strategies teachers employed to address the challenges. The interviews were a pre-interview (before the lesson observation, 1a) and post-interview (after the lesson observation, 1b). The interviews were taped and typed up. Data from classroom observations and interviews were then analysed thematically. The data from the teacher interviews revealed theoretical beliefs and perspectives on assumptions, pedagogical choices, and pedagogical practices related to GIS teaching at all levels (Grades 10, 11 and 12). Classroom observations provided information on the actual pedagogical decisions and practices used in the classroom.

To that end, the purpose of using interviews was to explore the experiences of geography educators teaching geography and, in particular, GIS, in the Frances Baard District. Semi-structured individual interviews were used to gather data for this study. According to Ravitch and Carl (2021) semi-structured interviews include a series of key questions that make it simple for participants to provide the information required to answer the research questions. In other words, the questions are structured in such a way that they solicit answers to the research questions and help discover hidden meaning, which would not be discovered by asking structured interview questions. This hidden meaning can be extracted through further probing of the interviewee. This type of interview is commonly used in qualitative social research. As a result, I chose semi-structured interviews over structured interviews because, unlike structured interviews, which begin with more general questions or a theme that the interviewer can pursue and probe to obtain more information, semi-structured interviewing begins with more general questions or a theme that the interviewer can pursue and probe to obtain more information. This leads to the interviewee being slowly drawn into more in-depth questions. Relevant themes can be recognised and significant connections between themes can be retrieved (Castillo-Montoya, 2016). The majority of the questions are formulated during the interview, giving both the interviewer and the participant flexibility and the opportunity to inquire into further details. The majority of the questions come up during the interview, allowing both the interviewer and the participant to inquire about specifics. The importance of probing is to get the participants to expand on their answers, provide more detail information, and add additional perspectives to constructs of interest. Because they encourage two-way communication, semi-structured interviews are also less intrusive to those being interviewed (Castillo-Montoya, 2016).

The interviews served two main purposes. Firstly, they elicited data on the pedagogical approaches used to teach GIS in high schools. Secondly, the interviews sought the views of geography educators on the effectiveness of the mechanisms employed by the basic education department towards teaching GIS in geography. (See the list of questions in Appendices A and B.)

This study adopted the semi-structured one-on-one interview before and after the lesson observation. The researcher employed pre-interviews and post-interviews. This interview method was used to get a comprehensive grasp of "the participant's views on, or perceptions or reports of, a certain topic" (Ravitch & Carl, 2021, p.134). In the present study, interviews sought to answer all the four research questions, as stated in Table 3.5. This method gave the researcher and the participants flexibility to ask questions for clarity, and to identify the attitude (facial expression) of the teacher as he/she responded to the questions that were asked. Furthermore, the researcher was able to probe particularly interesting themes that emerged during the interviews. The participants were motivated to share their experiences and perceptions, as they were perceived to be experts on the issues under discussion.

The researcher prepared the interview schedules for the educators (see Appendix B). The schedules provided the researcher with a set of predetermined questions that were used as appropriate instruments to engage the subject teachers (Clark-Carter, 2019; Adams & Lawrence, 2019). Having determined the key issues to be tackled in the interview, I outlined the broad range of themes to be covered in the interviews. The semi-structured interview questions were used to make sure that almost the same questions were retained and asked to the participants for the purpose of consistency and to avoid deviations from the issues being researched.

The interviews were carried out between January 2016 and March 2018, after the researcher had made appointments with school principals and subject teachers. Ten geography educators were involved in the interviews, and 50 teachers participated through the questionnaire survey. One interview and two lesson observations were scheduled for each educator. Each interview lasted 45 minutes to one hour. The subject teachers were given a copy of the interview schedule prior to the interview date, so that they could familiarise themselves with the questions that would be asked, though the schedule did not confine them to the questions listed – teachers were allowed to offer other insights during the interview. The researcher memorised the interview schedule in advance, to enable him to concentrate on what the teacher being interviewed was saying, and to monitor the coverage of the scheduled topic (Fox & Bayat, 2007; Bolderston, 2012; Cohen et al., 2018). The researcher wrote down notes, and recorded the interviews using a digital audio recorder. Recording was only done with permission of the participants. The audio recorder was very useful, as it enabled the researcher to concentrate on how the interviews proceeded. Other data generation methods, such as note taking, were used in cases where the participants were not comfortable with an audio recording being made.

When performing research efficiently, it is vital to employ the suitable research instruments (Marshall & Rossman, 2011). According to Marshall and Rossman (2011), the four core methods of qualitative research are participating in the environment, observing personally, conducting in-depth interviews, and examining documents and material culture. I used questionnaires, interviews (pre and post), and lecture observations to acquire primary data for this study.

Nuances of the in-depth Interviews

Semi-structured interviews were conducted with selected geography teachers to obtain in-depth data and an understanding of GIS teaching, as well as geography teachers' attitudes and views. This information aided the researcher in achieving the study's objectives. In-depth semi-structured interviews are used to uncover hidden issues that a structured interview is unlikely to reveal. These interviews provided me with access to critical information for the study that I would not have been able to obtain through a questionnaire survey (Welman et al., 2005). According to McNamara (cited in Valenzuela & Shrivastava, 2002, p. 2), "interviews are especially useful for getting the story behind a participant's experiences." Ten teachers were interviewed for this study (10 pre-interviews and 8 post-interviews). Only 8 post-interviews were carried out. This was due to shortage of time because the teachers were rushing to attend another lesson. The interview guide was created in response to the issues raised in the literature review chapter. The in-depth interview guide was divided into three sections and was intended to elicit insights from participants. The geography teachers' backgrounds were profiled in Section A. It consisted of three questions, to gather data on categories such as age, highest educational qualification and the race of the geography teachers, while the last question probed teaching experience.

Section B had 10 about questions. The first question asked about the GIS topics that are taught in geography. The second question asked the pedagogical approaches (teaching methods) used by the teachers when teaching GIS. The third question asked the teacher to provide reasons why he/she chose a certain pedagogical approach over others. The fourth question inquired about the teachers' thoughts on incorporating GIS into the geography curriculum. The fifth question asked about the implementation of GIS, in particular, whether the teacher found it easy or difficult. The sixth to ninth questions asked the teachers about their GIS knowledge, and how they rated themselves with regard to GIS knowledge. The last question in this section asked about the teachers' experiences of teaching GIS.

Section C covered the post-lesson observation questions. This section had two questions. The first question asked whether the teacher had succeeded in teaching all the concepts he/she had planned to teach in the lesson. The second question asked about the changes made during the lesson with regard to the pedagogical approaches used during the lesson delivery, and why this had occurred. This last section also sought to establish whether external circumstances can affect or force a teacher to deviate from the planned teaching and learning methods.

3.15.2 NON-PARTICIPANT CLASSROOM OBSERVATION

One of the data collection strategies employed was classroom observation. Classroom observation is defined as a process in which the researcher sees, hears, tests, and smells things (Liu, & Maitlis, 2010; Adams & Lawrence, 2019; Clark-Carter, 2019). Observation can thus be seen as "a natural part of any interaction process involving human beings" (Hopkins, 2002, p. 44). According to Creswell (2005), the process of gathering open-ended and first-hand information by observing activities at the research site is known as observation in qualitative research. Merriam (2009) stated that, one of the primary methods of data collection in qualitative research is classroom observations. She further argued that when combined with interviews and questionnaires, classroom observations provide a first-hand account of the situation under investigation and allow for a holistic interpretation of the phenomenon under investigation. Depending on the approach, philosophical paradigm, or research concerns that underpin the study, classroom observation might be structured or unstructured (Ravitch &

Carl, 2021). Structured observation is a discrete activity in positivist research that records physical and verbal behaviour. Observation schedules are planned in advance using classifications derived from well-known theory. Unstructured observation, on the other hand, is used to comprehend and construe cultural behaviour. It is based on the interpretivist/constructivist paradigm, which emphasizes the importance of situation and knowledge co-construction between the researcher and research participants (Rooney & Evans, 2019).

In this study, observation involved the researcher's visits to schools to witness what was actually happening during the GIS lesson, rather than depending on reported data. It gave the researcher an opportunity to observe GIS topics being taught in a natural context. This method is commonly used when a researcher wants to see consistency – in this case, the consistency of teachers' attitudes and their views on what occurs in their lessons. Observation enabled me to observe how the teacher concerned articulated the concepts taught/not taught. It enabled me to see whether the GIS topics were taught and if not, to probe further in the post-interview, to find out why this transpired. It also gave me the opportunity to see how the teacher implemented the pedagogical approaches, and to see how the learners were involved during the lesson. I could observe how the learners behaved whilst being taught, how the teacher stumbled, and what the learners did when they did not understand the content being taught.

Observations were not carried out to make the teachers uncomfortable, or used to find fault; instead, it was done to understand how teachers' attitudes/views do or do not influence their behaviour in relation to the teaching of aspects of GIS. Clarity was given to the teacher during the pre-interview, by ascertaining what would be taught in the lesson. This helped to put the teacher at ease and not to feel intimidated. As a result, observations of teachers' classroom practices were used as an additional data collection method to supplement data gathered through interviews and the questionnaire.

The purpose of the observations was to get a sense of the teachers' teaching practices in their natural environments. The expectation was that using the observation method would allow for the collection of a large amount of data that would not have been possible with interviews or a questionnaire survey. During classroom observation, I paid attention to the pedagogical approaches employed by the teacher. It also gave me the opportunity to observe the facial and body expressions of the teachers while they were teaching, and this information gave me a sense of the attitudes of the teacher towards the GIS concepts being taught.

It should be underscored that, in this research, I was specifically interested in observing and seeking to understand the following:

(a) How teachers help learners connect GIS with other related disciplines and other topics in the Geography curriculum.

(b) How teachers help learners link GIS with other related disciplines and other topics in the Geography curriculum.

(c) How teachers engage learners in learning GIS content in the lesson, as determined by the range of learner activities – group or individualised – the use of teaching and learning resources, such as instructional models developed by teachers and learners, including maps, diagrams, and concept maps, and assessing the types of questions asked by both teachers and learners.

I observed 10 lessons as part of this research. Each teacher was observed only once, due to time constraints, logistical problems and arrangements with the schools and the teachers. The lesson observation was done to ensure consistency and to capture the variation of pedagogical approaches used by different teachers and grades, and to note the attitudes of the teachers while they were teaching the GIS topics. I observed the geography teachers whilst they were teaching GIS during the first and second terms of 2016, 2017and 2018. The lesson observations were done during these terms, because this was when GIS concepts were taught, and the teachers were willing to be observed. Initially I had planned to observe at least two lessons per teacher. However, I abandoned this intention due to time constraints and timetabling challenges at some schools. The researcher was guided by an observation schedule during observations (Appendix C). The researcher used the observation schedule to document all teachers' instructional practices as well as some learner activities; I also observed at each stage of instruction, including the introduction, presentation, practice, and reflection.

As a non-participant observer, I intended to observe the interactions in the classroom without interfering with them. I had a plan for what I needed to observe, and I had a specific goal in mind. The GIS lesson observation framework included spaces to identify the observer, the teacher being observed, the school year, the date of the observation, and the observation number, the grade level of the lesson, and teaching strategies used. The checklist was divided into six components that are relevant to the teaching GIS. I recorded the lesson on audio since few of the teachers were comfortable with being audio recorded than video recorded. Instead, I used the checklist and field notebook to record what took place during the lesson.

There were a series of items under each component that represented criteria for evaluating the component's characteristics. The items of each component are analysed as follows:

Component 1: This component focused on the classroom climate. It considered the physical settings, learners' access to authentic GIS material, which includes equipment, such as projectors, datasets and computers, the provision of specially designated GIS materials, as well as a laboratory area for small-group instruction. The component also focused on the learners’ active engagement and social interaction, as well as practices that indicated that authentic GIS learning was valued, promoted and taking place during the lesson observation.

Component 2: The pre-lesson phase included items such as encouragement of the learners as the teacher prepared the learners for what to expect in the lesson, the drawing on prior knowledge so that the learners can connect ideas and concepts as well as the stimulation of interest in geography and GIS, in particular. This will be captured when the teacher recaps the previous knowledge from the learners as he/she tries to connect their prior knowledge with what will be taught in that lesson.

Component 3: This component focused on the teaching phase, which involved items such as an explanation of the concepts, confirmation of predictions, retelling, critical judgements, application of new vocabulary, concepts, and continued teacher monitoring of learner comprehension of the concepts taught during the lesson.

Component 4: The focus in this component was on the after-teaching phase. It involved aspects such as encouraging the learners do the task independently.

Component 5: This component focused on strategies and the provision of clear explanations and scaffolding.

Component 6: This component was concerned with the teacher’s practices of effective teaching strategies which scaffolded learners.

I methodically recorded what I observed during the 10 lessons. Each lesson observation session was followed by a five- to ten-minute interview session to clarify some of the classroom instructional processes. Data collected through observation was analysed alongside data collected through interviews. The goal was to see if the participants' perceptions and experiences matched what they actually did.

There are two basic ways of collecting data during classroom observations, and these are using anecdotal observations, and checklists (Hora & Ferrare, 2013). Anecdotal observations are classified as “wide” and “unrestricted” tools characterised by a blank sheet of paper. Checklist observations are “narrow” and “focused” tools, characterised by a microscope. Anecdotal observations simply involve writing down (or scripting) the actions of the teacher and the learners during the lesson observation (Olson & Foegen, 2007; Whitehead, 2020). This strategy is normally accompanied by documenting the event, where the researcher records the verbal and nonverbal behaviours of both the learners and the teacher during the observation.

CHECKLIST OBSERVATION

A checklist is defined as a form with items that direct one's attention and responses during the observation. It helps the researcher to follow a consistent pattern. There are a number of checklists that can be adapted in research. In this research I used both anecdotal observation and a checklist. I adopted anecdotal observation coding, which was developed by Olson & Foegen in 2007. Coding begins with taking note of the content addressed during the observed lesson. For each 10-minute period, I considered the expected task, the behaviours of the teacher, and the activities of the learners.

EXPECTED TASKS

The first step was to determine what task would be performed during the observation interval. The first step was to determine what task would be performed during the observation interval. This included identifying the type(s) of activity(s) that the teacher expected to occur during a specific 10-minute interval. There were eight possible expected tasks in this study. Warm-up activities, teacher-led instructions, homework checking, reviewing, working on an assignment, participating in group work, and no assignment tasks were some of the options. All of the anticipated tasks were coded, and the source of the activity and assignment, such as a textbook or worksheet, was noted. The following were the expected task codes:

Warm-ups are important (E-WU)

Instruction by a teacher (E-TLI)

Homework verification (E-CH)

a project (E-A)

Exam/quiz (E-TQ)

GIS-free (E-NGIS)

There is no assigned task (E-NAT)

TEACHER'S ACTIONS

I recorded whether the teacher's actions were instructional or non-instructional. I took note of whether or not the action promoted GIS learning. This code was entered in the correct column when determining whether the teacher action was instructional or non-instructional and I recorded them with the appropriate code. Conducting warm-ups, homework inspection, academic monitoring, administration of a test or quiz, leading a review, or giving a lesson are all examples of instructional activities (Olson & Foegen, 2007). In this research, additional codes, such as questioning, modelling, explaining content, and providing individual or group assistance, were added, since they are considered facilitating a lesson (Adams & Lawrence, 2019; Whitehead, 2020).

Non-instructional teacher actions were classified as task management (general non-instructional classroom tasks), behaviour management, being out of the room, or not teaching geography. The teacher action codes listed below were used:

Instructional

Warm-ups are carried out (T-WU)

Homework verification (T-CH)

Academic supervision (T-AM)

Conducting a test/quiz (T-TQ)

In charge of a review (T-LR)

delivering a lesson (T-L)

enquiring (T-Q)

Creating models (T-M)

Content explanation (T-E)

Providing one-on-one or small-group assistance (T-ISA)

Management of non-instructional tasks (T-TM)

Management of Behaviour (T-BM)

Leaving the room (T-OR)

Non-GIS related content (T-NG)

LEARNERS' ACTIONS

Learners' behaviours were categorised as productive or non-productive, and then further segmented, much like the teachers. Guided practice, orally answering questions, asking questions, seatwork (working on an assignment), group work, homework checking, and listening were all beneficial (used only when this seemed to be the predominant learner activity during a 10-minute interval). Non-productive behaviour was classified as disruptive, off-task, or non-GIS/geography. During the observation segment, as with the other categories, more than one label was used. The learner action codes listed below were used:

Productive

Guided practice that is beneficial (S-GP)

Answering questions verbally (S-VQ)

Posing inquiries (S-AQ)

Seating (S-S)

Examining/taking a test/quiz (S-TQ)

Homework verification (S-CH)

Collaborative effort (S-GW)

Paying attention (S-L)

Taking down notes (S-TN)

Non-productive

obnoxious (S-D)

Off-tasking (S-OFF)

Non-GIS/geography on-task (S-NG)

I went to the classroom to observe with a checklist containing what I wanted to observe. I ticked the items off on the checklist and scripted notes on an anecdote sheet, noting what was going on during the lesson. The checklist ensured that I did not omit some of the items I was looking for during the classroom observation. In addition, the anecdotal strategy gave me the opportunity to script some events that were not on the checklist. The anecdote form's handwritten notes were transcribed into Word documents, which were then printed to start the coding process. Although the coding can be analysed electronically using software such as Qualrus from The Idea Works (www.qualrus.com), I was unable to do so in this study due to a lack of software access.

IMPORTANCE OF CLASSROOM OBSERVATION

Classroom observations aided me in answering my research questions, particularly Objective 3, which sought to investigate the pedagogical/teaching methods used to teach GIS. The benefit of classroom observation was that it allowed me to see what the teachers were doing rather than what they said they were doing, which resulted in a more in-depth understanding of what was going on in the classroom than the data provided by the questionnaire survey. The disadvantage of classroom observation was that I was up close and personal with the teachers during their lesson presentation. I realized that this could lead to subjectivity on my part, jeopardizing the data's factual reliability (Merriam, 1998, p. 95).

The classroom observations took several months to be completed and they were not done consecutively. This was due to some schools which I visited, where GIS topics were not taught every term. Some teachers did not teach the concepts of GIS at all, and simply asked learners to revise past examination papers. I had to negotiate with the teachers to observe them. In addition, some teachers were not comfortable about being observed, hence, it took time for me to convince the teachers to observe their lessons. During each classroom observation, a specific detail from these observations was discussed. During the classroom observations, I used a checklist. The classroom checklist observation criteria helped me focus on aspects of the classroom that needed to be investigated before, during, and after teaching (Appendix C). The data from the classroom observations was coded, transcribed, and combined with the themes identified through the interviews and questionnaire analysis.

FIELD NOTES

Field notes are very important in research. Maxwell (2013), as cited in Ravitch and Carl (2021), raises a few concerns about field notes. They advise that keen observations and important conversations a researcher has in the field be documented so that the information can be fully utilized in a rigorous data analysis. The qualitative researcher's field notes also include what he or she saw and heard without interpretation. In other words, the primary task of the participant observer is to record without assigning feelings to the participants or deducing why and how something happened. In my case, the field notes helped me assess the subject of geography and accurately record what I heard and observed.

The data gathered through observation and the data gathered through interviews were examined concurrently. The goal was to see if the participants' perceptions and experiences matched what they actually did. In other words, observation was used to obtain an accurate picture of how GIS topics were taught, as well as to note the attitudes and perceptions of the teachers towards GIS, the depth of coverage of the concepts taught, and the pedagogical approaches used during the lesson. Similarly, data from classroom observations were used to compare and contrast with data from interviews and the questionnaire. The findings from classroom observations informed the findings deduced from data collected through other instruments, by presenting the teachers' actual beliefs and experiences regarding the teaching of GIS. The post-lesson-observation interviews conducted with teachers were carried out to solicit the teachers' reasons for utilising certain teaching strategies.

Muijs and Reynolds (2011) suggest that to be effective, classroom observation should be done using a standard instrument that guides the observer's notes about what he/she wants to observe. It is not easy to recall everything that was observed of classroom activities afterwards. In this research, I focused on pedagogical approaches employed by the teachers during the lesson. I also observed the classroom setup, teaching and learning materials used, such as charts and models, and teachers' facial expressions while they were teaching the GIS topics in different classes and grades, as well as when I was interviewing them.

3.15.3 QUESTIONNAIRE

Questionnaires are a simple way to collect information (Quinlan, 2011). A questionnaire, according to Dornyei (2014), is a series of questions designed to elicit statistical or personal information from individuals. Depending on the nature of the questions, questionnaires can be classified as quantitative or qualitative. Responses to closed-ended questions with multiple-choice answer options can be analyzed quantitatively, and the results can be displayed as pie charts, bar charts, and percentages. Furthermore, open-ended questionnaire responses can be analyzed using qualitative methods, which may include identifying themes and conducting discussions and critical analyses of the main themes without the use of numbers and calculations.

Because the quantitative data gathered through the questionnaire survey in this study was descriptive in nature, statistical tools were utilised to describe and interpret the numerical data (Clark-Carter, 2019; Ravitch & Carl, 2021).

ADMINISTERING THE QUESTIONNAIRE

I prepared 70 questionnaire sets and distributed them to the qualified teachers who were already teaching geography in the FET phase (Grades 10, 11 and 12 at high schools). Fifty of these questionnaire sets were distributed to geography teachers who had congregated at the Elizabeth Conradie School on 23-26 March 2017 for a workshop to discuss the 2016 geography matric results. The questionnaires were distributed on 24 March 2017. Most of the teachers were able to complete the questionnaire questions and return them the following day, on 26 March 2017. The other 20 questionnaire sets were randomly distributed to teachers who teach geography in the study area in the Northern Cape province. I visited the schools and gave the questionnaires to the geography teachers. Out of the 70 questionnaires distributed, 50 were completed and returned to the researcher. This means that 71.4% of the questionnaires were returned, which is a statistically significant achievement.

STRUCTURE OF THE QUESTIONNAIRE

The questionnaire instrument (Appendix A) consisted of 36 questions, which were divided into six sections.

Section A contained three questions. These questions enquired about the participants' biographical data, and were closed questions, which required the teachers to indicate their responses by ticking the options provided. The questions asked for data on age, gender, race and qualifications of the participants. This requirement is in line with Adams and Lawrence (2019), who state that these attributes are necessary when one wants to understand the type of participants, he/she is dealing with. In this research I wanted to understand whether age, level of education and gender have a bearing on the adoption of GIS.

Section B of the questionnaire had six questions. The questions focused on the type of school, teaching experience, number of periods taught, professional qualifications and area of specialisation. This section sought to provide the researcher with insights into the type of teachers involved in the research and, in particular, their teaching experience and qualifications.

Section C had one question, which enquired about the availability of physical GIS resources/infrastructure at the school. This question sought to gauge the possibility of applying the practical teaching of aspects of GIS at the schools.

Section D had 14 questions, which focused on GIS concepts, pedagogical approaches/teaching and learning methods and professional experience of teaching GIS in geography. The section had seven open-ended questions, and required the teacher had to write a response, and seven other questions that required the teacher to select a response by ticking on the response options provided. The questions sought to measure the knowledge, skills and experience of the geography teachers with regard to GIS. The other questions investigated the pedagogical approaches used to teach the concepts of GIS and the aspects of GIS taught in Grades 10, 11 and 12.

Section E had two questions, both of which asked about the teachers' professional experience of GIS.

Section F, the final section, sought to ascertain geography teachers' attitudes toward GIS. In this section, participants' responses were recorded using a Likert scale. A Likert scale, according to Adams and Lawrence (2019), Clark-Carter (2019), indicates the degree to which participants agree or disagree with given statements. On a 5-point scale, 1 meant strongly disagree, 2 meant disagree, 3 meant neutral, 4 meant agree, and 5 meant strongly agree. This scale was used to gain insight into high school teachers' attitudes and perceptions of GIS teaching. The score is presented in ascending order, with the highest score indicating the most positive reaction (DeCastellarnau, 2018).

PROCESSING AND ANALYSING DATA

Data analysis is an essential component of research, and there is no "right" way to contact data analysis (Ravitch & Carl, 2021. p.233). It entails examining primary data in order to comprehend the problem under consideration (Harding & Whitehead, 2013).

Before data analysis, the questionnaires were checked for errors. To capture quantitative data in diagrams, graphs, and pie charts, the Statistical Package for the Social Sciences (SPSS) computer software was used. Responses to each research question were also analysed using descriptive and inferential statistics. For ease of reference, the results were presented in tables and figures. The researcher benefited from this presentation as he continued to analyse and interpret the SPSS results.

The first step, after receiving the completed questionnaires from the participants, was to create an identity number (ID#) for each questionnaire set received. As a result, ID# from 1 to 50 were created. All the answers on the questionnaire were entered into Excel first, and then exported to IBM-SPSS Version 25 for a logical batched and non-batched statistical analysis. Variables that addressed the availability of computing facilities were categorical rather than ordinal, hence, Chi-square tests of association were more appropriate for testing their association with other categorical variables, such as the demographic variables. To examine the relationship between two categorical variables, the Fisher's Exact test was used because some of the cells had very low frequencies (frequencies below 5). When cell sizes are expected to be large, the Chi-square test is used. For variables on the Likert scale, t-tests were used to compare two categories and analysis of variance (ANOVA) tests were used to compare more than two categories. To present and describe the gathered data, descriptive statistics were used (Meyer, 2009). The researcher profiled participant responses and presented the findings using frequencies. Because all constructs were classified differently, results were presented using tables. The frequency distribution displays the number of people who participated in each variable.

The findings of this study are presented as responses to each of the research questions. The biographical details of all the participants were considered and helped to create a visual image of the participants.

The analysis of qualitative data is a non-mathematical procedure. for analysing people's words, behaviour, attitudes, perceptions, and beliefs (Harding & Whitehead, 2013). In-depth interview data was written down and divided into small chucks in order to identify themes consistent with the research objectives. This method was used to examine qualitative data. To get a conclusive analysis and proper theme analysis, it is necessary to thoroughly study collected data, select key areas of attention, and classify information. Seven steps were taken into consideration when analysing the data. Among these steps as noted by Onwuegbuzie and Combs (2011,p.28) are "data reduction, data display, data transformation, data correlation, data consolidation, data comparison, and data integration".

This research used the framework approach to analyse the data that was collected using interviews and lesson observations. The framework method is part of a broad family of analysis methods that includes thematic analysis and qualitative content analysis (Gale et al., 2013). The main purpose of these approaches is to identify cohesions and differences in the data, before focusing on connections the data might have so that comprehensive conclusions may be reached. This differs from completely inductive approaches like grounded theory, where research is an iterative process that grows in response to evidence collected and via continuing analysis.

Qualitative data analysis is constantly on the lookout for concepts and themes that, when combined, will provide the most comprehensive explanation of "what's going on" in an investigation (Gale et al., 2013, p.6). The framework approach (discussed below) has recently gained acceptance as a method of analysing qualitative data because it can be used to handle qualitative data and conduct systematic analysis (Ravitch & Carl, 2021). This method allows the researcher to undertake in-depth data analysis while preserving an effective and transparent audit trail, enhancing the rigor of analytical methods and the trustworthiness of the findings (Gale et al., 2013, p.7).

3.15.4 APPLICATION OF THE FRAMEWORK APPROACH

For a variety of reasons, it was decided to use the framework approach for data analysis. Firstly, the method is ideal for analysing cross-sectional descriptive data and capturing various aspects of the phenomenon under investigation. Secondly, it makes the researcher's interpretations of participants' experiences transparent. Third, the framework approach, which makes the method simple to adopt, precisely specifies the steps that lead the systematic analysis of data, from initial management to the generation of descriptive explanatory accounts.

The following key questions were used to guide the discussion in the semi-structured interviews:

Table 3.5: Research questions used

	Research questions used
1	What are teachers' attitudes towards GIS in geography in the FET curriculum?
2	What are the teachers' views about GIS in geography in the FET curriculum?
3	What are the pedagogical approaches/methods used to teach GIS?
4	Why do teachers use these pedagogical approaches to teach GIS?

The research questions listed Table 3.5 guided the interviewer to explore the educators' perceptions and attitudes in relation to teaching GIS topics that were taught during the research period. The interviews and lesson observations were conducted to obtain data on the perceptions and attitudes of educators who teach GIS. The interviews were conducted face-to-face with educators and transcribed verbatim.

Thematic analysis was then used, and this can be approached in a variety of ways (Boyatzis,1998; Alhojailan, 2012; Javadi & Zarea, 2016). The main goal of a thematic analysis is to find patterns in data that are important for answering research questions or saying something about an issue. Maguire and Delahunt (2017) state that thematic analysis involves summarising the data, interpreting it and making sense of the data collected. Byrne (2021) also highlight that researchers should not use the main interview questions as the themes.

Braun, Clarke, Terry and Hayfeld (2018) distinguish between two types of themes: semantic and latent. Semantic themes refer to the data's superficial meanings, and the analyst is only interested in what a participant has said or written. The analysis in this study identified semantic themes that include attitudes towards GIS inclusion in the geography curriculum, perceptions on GIS teaching, pedagogical approaches used in teaching GIS, and reasons why teachers used particular approaches to teach GIS. In contrast, the latent themes consider more than what has been said. It begins by identifying the underlying ideas, assumptions, and conceptualisations and ideologies and then looking at the theories the outcomes of the results (Braun, Clarke & Weate, (2016).

Six steps should be followed when doing thematic analysis (Braun & Clarke, 2006) (see Table 3.6).

Table 3.6: Braun and Clarke's six-phase framework for thematic analysis

Step 1: Become acquainted with the data,	Step 4: Go over themes again,
Step 2: Create themes,	Step 5: Establish themes
Step 3: look for themes,	Step 6: Write a report

The difference between framework and thematic analysis is only a small extension of the thematic analysis. These steps do not need to be linear – a researcher can start at any step and can move forward and backwards between the steps (Braun & Clarke, 2006).

Step 1: Become familiar with the data

Reading and rereading the transcripts is the first step in any qualitative analysis. An example of an interview extract is provided in Appendices B and D.

Step 2: Generate initial codes

This stage is concerned with organizing the data in a meaningful and systematic manner. Coding aids in the reduction of data into small chunks of meaning in this step. There are various methods for coding, and the method is determined by the research questions. In this study, I was concerned with answering specific research questions, and I had to identify the themes that provided answers. As a result of the nature of the research, I was compelled to use a theoretical thematic analysis approach rather than an inductive one (Maguire & Delahunt, 2017).

I used open coding, which means I did not use pre-set codes and instead developed and modified them as I went through the coding process (Maguire & Delahunt, 2017). I went through each transcript, coding every piece of text that seemed relevant and addressed the question. As I worked through the transcripts, I generated new codes and sometimes modified the ones initially created. This is in line with Maguire and Delahunt's (2017) suggestion that the initial codes can be modified and changed as one goes through the transcripts; the process is not linear, and the researcher has to understand the data and modify it in ways that make sense to him/her. I started by hand, going through hard copies of the transcripts with a pen and highlighter. For example: These extracts were taken from the transcribed interviews:

Mr Douglas explained that:

Example of coding

GIS topics lack content and activities I can use and teach the learners. I find it challenging to teach these topics. I think it was going to be much easier if I had a computer with GIS software. I would be able to show some of the concepts and make my explanation and teaching much easier.

Ms Abigal stated :

GIS topics are difficult to teach because as you can see learners do not have enough resources. Most of the times they share textbooks and some of them they do not come to school with their text books. The class is overcrowded as you can see.

Codes

Green colour: lack of **physical materials** (such as textbooks, computers, topographical maps, GIS software)

Yellow: indicates the **challenges/difficulties** teachers face

Blue: indicated the **large classes** teachers teach

Step 3: Search for themes

This step fine-tunes the themes that were identified in Step 2, so that they address the research questions. In this case, I examined the codes and combined some to form a single theme. For example, I had several codes that related to the geography teachers' perceptions and views on teaching. I collated some of the codes into one theme, "GIS is difficult to teach without a laboratory".

Step 4: Review themes

During this phase, I reviewed, modified, and expanded on the initial themes identified in Step 3 to see if they made sense and answered the research questions. At this point, it is a good idea to collect all of the data relevant to each theme. I read the data associated with each theme and considered whether it was relevant and supported the theme. The following step was to consider whether the themes worked across the entire dataset. My analysis was guided by Bree and Gallagher, (2016) as well as Maguire and Delahunt's (2017) suggestion that the themes should be coherent and different from each other. These are some of the issues that I considered:

- Are the themes clear?
- Do the data back up the themes?
- Am I cramming too much into a theme?
- Are overlapping themes actually separate themes?
- Are there subthemes (themes within themes)?
- Are there any other themes in the data?

Step 5: Define themes

This is the final stage of theme refinement, and the goal is to "identify the 'essence' of what each theme is about" (Braun & Clarke, 2006, p. 92). At this point, I was trying to figure out what the theme meant. If there were subthemes, I had to figure out how they related to the main theme. Table 3.8 lists the procedures that were followed when I analysed the qualitative data that had been collected through interviews and questionnaires.

Table 3.7: Questions that served as the framework for the analysis

Question 1	What are the numbers saying to me? (Explicitly demonstrating theoretical, objective, ontological, epistemological, and field comprehension)
Question 2	What exactly am I looking for? (In accordance with the objectives, questions, and theoretical interests of the research)
Question 3	What is the dialectical link between what the facts tells me and what my intuition tells me? I am interested in learning? (Sharpening the focus and returning to the research questions)

Table 3.8: Application of the framework to refine focus and integrate data

Point of interest: Aspects of GIS being taught by high school teachers as part of the geography curriculum. *The initial focus/point of interest*

Question 1: What do the numbers tell me?

Data from Teacher 1

What does the interview data from Teacher 1 indicate about aspects of GIS?

What do the interview data from Teacher 1 suggest about pedagogical approaches?

What do the interview data from Teacher 1 inform me about the reasons of using the particular pedagogical approaches, instead of other approaches?

What do the interview data from Teacher 1 tell me about the attitudes of teachers about the inclusion of GIS in the geography curriculum in the FET phase?

What do the interview data from Teacher 1 tell me about teachers' perceptions/views and experiences with GIS integration in the geography curriculum?

What does the data from Teacher 1's interview reveal about the challenges of GIS?

Question 2: What do you want to know?

I'm curious about the actual pedagogical approaches used by teachers to teach GIS.

Fine-tune your point of interest/focus.

Question 3: What is the dialectical relationship between what the data indicate and what I am interested in learning?

Integrate observation data from interviews with teachers and data from observed lessons.

Re-examine the teachers' formal interview data.

Rep the process of Question 1 for all of the teachers interviewed.

The dialectical relationship (Question 3) between my initial interest in pedagogical approaches and continuous rounds of integrating all the data from teachers' interviews and classroom observations eventually led to a more refined focus on explicitly articulating the differences between various pedagogical approaches used by different teachers. These approaches later became the research's major findings (Srivastava, 2008).

3.16 LIMITATIONS OF THE STUDY

One significant limitation of case studies is that "we cannot be certain that the findings are generalizable to other situations" (Leedy & Ormrod, 2016, p. 137). Furthermore, because this is a pragmatist study, a small sample was chosen to represent geography teachers from a large number of teachers across several provinces. This research was limited to selected high school teachers in the Northern Cape province in the Sol Plaatje Municipality’s Frances Baard District. As a result, the findings are limited to this micro-location and do not apply to all high school geography teachers in the Northern Cape province as a whole.

Furthermore, while questionnaires were sent to high schools in other districts of the province, the face-to-face interviews and lesson observations were limited to high schools in Frances Baard District. The study was, nevertheless, undertaken at both rural/peri-urban and urban high schools, in order to obtain a balanced view of teaching on the topic being researched.

Thus, the findings provided an understanding of the views and attitudes of and the pedagogical approaches generally used by geography teachers for teaching GIS. However, numerous disruptions occurred during the data generation process. These are discussed below.

Data was generated from geography teachers working in public and private high schools. Face-to-face interviews, lesson observations and questionnaires were used to generate data for this research.

First, I was referred to the principal, to ask permission to talk to the teachers concerned. After talking to the principal, the head of department referred me to South African Democratic Teachers' Union (SADTU) chairman at the school, who refused permission to interview the teachers. I went over the research's goal in detail with them and handed them the ethical approval documents I obtained from the provincial Department of Education and the University of KwaZulu-Natal, but the SADTU representative stated that they were unable to grant me permission to conduct interviews with their members because the provincial SADTU chairman had not been notified. They were adamant, even though I indicated that the data to be collected would be used solely for research, and the findings from the research would help to improve the teaching of GIS, and geography education, at high schools.

Secondly, I was refused permission to conduct interviews at one of the Afrikaans medium schools in Frances Baard district. The secretary informed the appropriate teachers about my research and then contacted me to inform me that I would not be able to interview the participants. The teachers would be uncomfortable being interviewed in English by someone who did not speak Afrikaans, according to the reasoning. As a result, the medium of communication (language) influenced my choice of participants for this study, as did claims of possible victimization by the union, SADTU.

3.17 ETHICAL CONSIDERATIONS OF THE STUDY

Ethics is defined as "a set of moral principles and rules of conduct," whereas ethics in research is defined as "the application of a system of moral principles to prevent harming or wronging others, promote the good, be respectful, and be fair" (Sieber, 1993, p. 14). According to Webster, Lewis, and Brown (2014), it is critical that researchers respect their participants' constitutional rights, privacy, dignity, and emotional state, as well as the integrity of the organization in which the research is conducted. As the researcher, I worked hard to meet these requirements. According to Webster et al. (2014), there are two types of consent: informed consent and written consent. Informed consent ensures that participants have all of the necessary information before deciding whether or not to participate in the research; this information includes the "aims, funders, researchers, what will be involved, and anonymity and confidentiality" (Webster et al., 2014, p.109). Written permission, on the other hand, is a document signed by the participant acknowledging their acceptance of the research study's terms. In this study, I used a written consent method. As a result, after obtaining an explanation of the study's background and objectives, all participants were asked to sign the consent form after being guaranteed that I would follow the expected ethical principles of research.

Before the interview and lesson observations, I explained the purpose of the study to the participants and read the consent form to them slowly. Before the interview, any issues that arose were clarified, and the participants confirmed their participation in the study by signing the consent form. The consent form included information about the purpose of the study, as well as the participant's role and contributions. All participants were assigned pseudonyms to protect their identities, ensuring their anonymity (Ravitch & Carl, 2021). Confidentiality is required to keep participants safe and to protect their right to privacy (Rooney & Evans, 2019; Clark-Carter, 2019). Participants were told that if they were unhappy with their involvement, they could leave the study at any moment. The research data will be erased after five years by shredding all study documents and permanently deleting any voice recordings.

3.18 VALIDITY

It is suggested that a research study's data collection process has ramifications for the research's validity and reliability (Creswell & Poth, 2018; Adams & Lawrence, 2019; Ravitch & Carl, 2021). Because validity is not a single, fixed, or universal notion in qualitative studies, it is described by a number of terminologies. It is "rather a contingent construct, intimately grounded in the processes and purposes of individual research procedures and projects" (Winter, 2000, p.1). Validity refers to the overall experimental concept and assesses whether the produced results meet all of the scientific research method's requirements. In other words, the accuracy of researchers' interpretations of their data refers to the validity and reliability of qualitative research (Creswell & Poth, 2018). Validity also refers to the dependability of researchers' interpretations of their data (i.e., over time, location and conditions).

There are three types of validity that can be used in qualitative research, namely: according to descriptive validity, interpretive validity, and theoretical validity (Johnson & Christensen, 2004). First, descriptive validity refers to the account's factual correctness as described by the qualitative researcher. Second, interpretive validity seeks to determine whether the qualitative researcher correctly understands and conveys the participants' views, ideas, intentions, and experiences. Thirdly, theoretical validity investigates whether a theory or theoretical description is derived from a research study that is consistent with the data and, as a result, is dependable data that can be defended (Johnson & Christensen, 2004). This research study employed all three types of validity. Furthermore, interpretive validity was used during the face-to-face interview discussions by asking participants to elaborate on specific responses they gave during the interview in order to determine whether their thoughts were a true reflection of what they had stated. Finally, the data's dependability was ensured.

Internal validity is used to ensure that the research instrument measures what it is supposed to measure, whereas validity is used to determine whether or not the data can be generalised across and beyond the scope of the research context (Leung, 2015). The appropriateness of the research instrument's content is referred to as content validity. As a result, the questionnaire was given to experts at Sol Plaatje University's School of Education to evaluate the validity of both the instruments and the content. To assess the validity of the measuring instruments used in the study, a two-phase pilot test was conducted.

A pilot test, according to Denscombe (2014), is the testing of research instruments on a subset of a research sample to assess participants' reactions when completing the research instruments before the main study is conducted. The primary goal of conducting a pilot test is to identify and eliminate any complications associated with research instruments. Positive pilot test results, according to Denscombe (2014), indicate that the research instruments may yield the same outcomes when used on other participants.

For this study, a two-phased pilot test was conducted. The first phase of the pilot study included two in-depth interviews with the researcher and a geography teacher at a nearby high school. The second phase consisted of a questionnaire survey, administered to five geography teachers by the researcher in the township high schools. These pre-tests were carried out to ensure the instruments' dependability and consistency. The feedback from the pilot tests was used to fine-tune the research instruments (interview guide and questionnaire survey instrument). The results of all pre-tests were incorporated into the data. Furthermore, these adjustments were used to investigate various insights that had been overlooked when the measuring instruments were initially designed.

3.19 RELIABILITY

Although the term dependability pertains to the concept of testing or evaluating quantitative research, it is commonly used in all types of research (Clark-Carter, 2019). An analysis of trustworthiness is required to assure reliability in qualitative research. The degree to which a measure produces consistent results from one instance to the next is known as dependability.

The research instrument is dependable if the results of a study can be replicated using same technique and instruments (Clark-Carter, 2019)

The idea of replicability or repeatability of results or observations emphasizes that when you apply the same method to the same sample under the same conditions, you should get the same results. If this is not the case, the measurement method could be untrustworthy (Middleton, 2019). As a result, I agree with Middleton (2019, p.1), who identified four types of reliability in quantitative research namely: “the degree to which a measurement can be applied repeatedly and remain constant; the stability of a measurement over time, which means that the same test performed by different people produces the same results; the similarity of measurements within a given time period; and internal consistency”. Reliability in this study was enhanced through detailed fieldnotes, transcribing and carefully checking the transcriptions.

3.20 CONCLUSION

The research design and methodology used in this study was presented in this chapter. It highlighted critical research elements used in this study, such as the research paradigm, study area context, research design, research population, sample size, sample technique, data collection methods, and data analysis. Furthermore, the chapter outlined, how reliability and validity issues were dealt with by this study. The following chapter presents the findings of the research.

CHAPTER 4: FINDINGS

4.1 INTRODUCTION

This chapter discusses the quantitative and qualitative results of this research. The findings are displayed as responses to the research questions of the study. The research questions as stated in Chapter 1 and 3 are repeated below. The chapter is divided into two sections. Section A comprises the profiles of the participants, namely the demographic traits of the teachers who participated in this research, while section B presents the quantitative and qualitative results integrated together.

The findings responded to the study's objectives and the critical questions of the research. There were four critical objectives in this study.

What are teachers' attitudes towards GIS inclusion in geography in the FET curriculum?

What are the teachers' views about GIS in geography in the FET curriculum?

What are the pedagogical approaches/methods used to teach GIS?

Why do teachers use these pedagogical approaches/methods to teach GIS?

Research response rates

In quantitative data sets, the response rate of an instrument carries significance, however, this is not of value in qualitative data. The response rate of the only quantitative instrument, namely the questionnaire is presented in Table 4.1.

Table 4.1: Response rate

Research activity	Participants	Target number of participants	Responses		Phase of primary data collection
			N	%	
Questionnaire survey	Geography teachers	70	50	71.4	Phase 1
In-depth-interviews Lesson observation	Geography teachers	15	10	66.7	Phase 2

However, I choose to also provide an indication for each of the qualitative instruments although it has no bearing on the validity of these two instruments.

The targeted sample size for this research was 85 geography teachers. The use of two samples resulted from the use of a mixed method technique, specifically the explanatory sequential mixed research design. As a result, 70 teachers were chosen to take part in the questionnaire survey (quantitative data collection) while 15 geography teachers were targeted for the in-depth interviews and lesson observations (qualitative data collection).

A total of 70 questionnaires were distributed to geography teachers, with 50 returned to the researcher. The response rate was 71.4%. The high response rate was primarily due to some questionnaires being distributed and returned while the teachers were attending a workshop in Kimberley. Furthermore, participants were asked to return the questionnaire to the District Department of Education, where the researcher would collect them.

For the qualitative data collection, appointments were made with the 15 geography teachers to carry out in-depth interviews and lesson observations for the second phase of the study. Out of the 15 teachers targeted in the study area, I managed to interview 10 teachers and observed them teaching different topics in GIS. Some of the teachers were not keen to have their lessons observed and in some schools the teachers were barred from being interviewed and having their lessons observed as they were members of the largest teacher union, the South Africa Democratic Teachers Union (SADTU), which had collectively made this decision due to a dispute with the Department of Education. The response rate for the qualitative data set was 66.7%.

4.2 SECTION A: DEMOGRAPHY AND TEACHING ENVIRONMENT

The purpose of this section is to provide the demographic results from both the questionnaire surveys and interviews in this study. During the study, participants were asked about their gender, age, race, highest educational qualification, area of specialization, the type of school they teach at, and teaching experience (See Question 1 and 2, Appendix A). The results of 50 participants are discussed in the following section.

Table 4.2: showing the age, gender and race of the 50 participants from the questionnaire (n=50)

Demographic Variable		Frequency	Percent
Age	26-29 Years	12	24%
	30-39 Years	16	32%
	40-49 Years	17	34%
	≥50 Years	5	10%
Gender	Female	16	32%
	Male	34	68%
Race	Black African	28	56%
	White	7	14%
	Coloured	15	30%

Table 4.3: showing the age, gender and race of the 10 participants who were interviewed (n=10)

Demographic Variable		Frequency	Percent
Age	26-29 Years	3	20%
	30-39 Years	0	0%
	40-49 Years	4	30%
	≥50 Years	3	40%
Gender	Female	4	40%
	Male	6	60%
Race	Black African	4	40%
	White	2	20%
	Coloured	4	40%

4.2.1 GENDER

The empirical results for gender distribution are shown in Table 4.2 and Table 4.3.

The findings revealed that male teachers dominated the study in both data sets (questionnaire and interview data). Male teachers constituted 40 (66.67%) of participants, while female participants amounted to 20 (33.33%) of the participants. This result reflects a fair gender representation, because the study sought to glean insights from a diverse and balanced gender distribution of geography teachers in the study area.

4.2.2 AGE DISTRIBUTION

Most of the participants in this study were relatively young teachers ranging 26-29 and 30-39 years of age. The age distribution of the participants is shown on Table 4.2 and Table 4.3.

As indicated in Table 4.2 the age distribution showed a fairly even distribution of all age groups in the study area with slightly higher frequencies in the middle age groups, that is, the 30 to 39 (32%) and 40 to 49 (34%) age groups. The majority (n = 17) of the geography teachers who participated were in the 40-49 years' age category. This majority of teachers constitute 34% of the participants by the questionnaire survey, while the 30-39 age group represented 32% of the participants. The data from the participants who were interviewed also showed similar trends, age group from 26-29, 30-39 and 40-49 was dominating. Teachers who were over 50 years had the lowest representation overall. This was due to some teachers opting to retire earlier. Also, the demography of the participants was dominated by males with fewer females. This shows a fair age distribution for the study and a true reflection of the demography of the population of teachers in the schools in this study area.

The study comprised of more males (66.67%) than females (33.33%), hence the general findings in this study will predominantly mirror the views and attitudes of more males than females. There are more male geography teachers than females because there are few females who take geography as a subject from high school up to university level (Maduane, 2016). The reasons for this skewedness are not very clear and not well researched in the literature. There is also greater representation of Black Africans (56%) than other races but this is due to the study being in South Africa where the majority population is Black African.

4.2.3 RACIAL DISTRIBUTION

The empirical findings show that black African geography teachers dominated the survey in both data sets. In total there were 32 black African teachers, 18 Coloured teachers and 10 White teachers who participated in this research (Table 4.2 and Table 4.3). Coloureds had the second highest number of participants and White participants were the smallest group (Table 4.2 and Table 4.3). It is salient to note that some schools in the province are using Afrikaans as medium of communication and not English and as such I was not able to do the interviews and lesson observations in those schools because of the language barrier. I do not speak and understand this local language, namely Afrikaans. I thus concentrated on those schools where

English is the medium of communication and where the majority of the teachers were black Africans.

4.2.4 EDUCATIONAL LEVELS OF THE PARTICIPANTS

The results on the highest educational levels of participants through the questionnaire are indicated on Table 4.4. The results indicated that (44%; n = 22) of the geography teachers had Bachelor of Education degrees (B.Ed.), 26% (n = 13) had Bachelor of Science (BSc) degrees, 12% (n = 6) had Bachelor of Arts (BA) degrees, 14% (n = 7) had Postgraduate Certificates in Education (PGCE), and (4%; n = 4) had master's degrees of the participants from the questionnaire Table 4.4. The geography teachers who participated in this research were qualified and some have been in the teaching profession for a long period of time. However, among these teachers some did not major/specialise in geography during their training. 46% (n=23) of teachers specialised in history and the languages and 6% (n=3) stated that they trained in other subjects, yet they were teaching Geography. Also, the findings from teachers who were interviewed revealed similar trend that there some teachers who were teaching geography who did not specialise in the subject 30% (n=3) specialised in social sciences and languages and 10% (n=1) specialises in other subject when they were doing their training (see Table 4.4 and Table 4.5).

Table 4.4: Teaching background and summary of the researched participants (n=50).

Teaching background/set up		Frequency	Percent
Type of school	Private	6	12%
	Public	44	88%
Teaching Experiences	0-4 years	12	24%
	5-9 Years	11	22%
	10-14 years	22	44%
	Over 15 Years	5	10%
Teaching Periods per week	4 hours	18	36%
	5hr 30mins	23	46%
	6 hours	9	18%
Number of Learners in the class	16-29	9	18%
	30-39	17	34%
	above 40	24	48%

Academic highest qualifications	B.Ed.	22	44%
	Bsc	13	26%
	BA	6	12%
	PGCE	7	14%
	Masters	2	4%
Area of specialisation	Geography	24	48%
	Social Sciences	3	6%
	Others	23	46%

Table 4.5: Teaching context (n=10)

Teaching background/set up		Frequency	Percent
Type of school	Private	3	30%
	Public	7	70%
Teaching Experiences	0-4 years	2	20%
	5-9 Years	0	0%
	10-14 years	4	40%
	Over 15 Years	4	40%
Teaching Periods per week	4 hours	3	30%
	5hr 30mins	7	70%
	≥6 hours	0	0%
Number of Learners in the class	16-29	0	0%
	30-39	3	30%
	above 40	7	70%
Academic highest qualifications	B.Ed.	6	60%
	Bsc	1	10%
	BA	0	0%
	PGCE	3	30%
	Masters	0	0%
Area of specialisation	Geography	6	60%
	Social Sciences	3	30%
	Others	1	10%

4.2.5 TEACHING EXPERIENCE

Table 4.4 shows the years of teaching experience of the teachers involved in the study from the questionnaire survey. Most of the participants (44%; n=22) had teaching experience ranging between 10-14 years (44%), while 24% (n=12) had teaching experience of 0-4 years. The findings from the interviews and observations of teachers' lessons revealed a similar pattern. The participants were also made up of teachers who were novice teachers, who had recently joined the teaching profession between 0-4 years (n=4) and those who were seasoned teachers: having between10-14 years (n=3) of teaching experience and those who had over 15 years of teaching experience (over 15 years; n=5). The results on the distribution of teaching experience depict a normal distribution, from teachers with vast experience of the profession, and others who had just joined the profession of teaching. Overall, quantitative and qualitative data sets revealed that the majority of teachers had 10-14 years of experience and more than 15 years of experience (see Table 4.4 and Table 4.5).

4.2.6 AREAS OF SPECIALISATION

Although the majority were qualified, 48% had geography as their specialisation, 6% specialised in Social Sciences and 46% specialised in other subjects (Questionnaire survey data). Data from the interviewed teachers showed that 60% (n=6) specialised in geography, 30% (n=3) specialised in Social Sciences, which is a combination of Geography and History and 10% (n=1) specialised in other subjects (Table 4.4).

4.2.7 CLASS SIZE

The majority of the participants (48%; n=24) reported that they teach more than 40 learners per class, 34% (n = 17) of the teachers teach classes that range between 30 and 39 learners, while 9 teachers reported teaching 16-29 learners per class. It is evidently clear that the majority of teachers have large Geography classes of more than 40 learners in a class. The small sized classes were mainly found in former C Model schools and in private (independent) schools while large classes were found in townships and rural schools. The reasons for small size classes in former C Model schools and private schools could be that the parents of learners at these schools pay school fees and they can afford to hire extra teachers through the School Management Boards (SGB). Also, the high school fees paid in these schools tend to deter learners from poor families from these schools. The public schools in the townships and rural areas which are non-school fees payment tend to be overcrowded (Mohamed, 2020; Burnett, 2021) because most of the learners attend these schools because their parents cannot afford to pay the school fees in other schools. These public schools are under resourced when compared to the former C Model schools (which are now classified as public schools as well) and private schools (Mohamed, 2020).

4.2.8 TYPES OF SCHOOLS

The majority of the teachers (88%; n=44) who participated through the questionnaire survey in this research taught in public schools (rural and urban), and only 12% taught in private schools. Data from the interview and lesson observation tools showed that 70%; n=7 were from the urban schools and 30%; n=3 were from rural schools (see Table 4.4 & Table 4.5).

4.3 DATA ANALYSIS

The data gathered from the questionnaires was analyzed using descriptive statistics such as frequency counts and percentages, Fisher's exact test, and Kruskal-Wallis. Fisher's exact test is a statistical significance test used in contingency table analysis (Fisher, 1954). Fisher's exact test was used to test association levels of the variables tested. It was used because the sample sizes were small. When the total sample size is smaller than 1000, Fisher's exact test is employed. In this research the sample size for the questionnaire was 50. The sample size of 50 was used due to time constraints and few responses received from the teachers I sent the questionnaire in Frances Baard District where the research was done. If the sample was large Chi-square or G-test was going to be used (McDonald, 2014). The test proved useful for categorical data resulting from two different classifications of things. It is used to see how important the relationship (contingency) between the two types of classification is. In this research Fisher's exact test and Kruskal Wallis were used to find out if there was statistical significance among the variables such as age, qualification, types of school, gender vice versa the knowledge of GIS, effectiveness of GIS as a teaching tool in geography etc.

To test for differences between two groups the Wilcoxon tests was used and for differences among more than two groups the Kruskal-Wallis test was used. The Kruskal-Wallis test is a form of nonparametric Analysis of Variance (ANOVA) which can be applied to ordinal data or any data that does not conform to the assumptions of parametric ANOVA. It is a test used to determine whether or not there is a statistically significant difference between the means of two or more populations. It describes the variance within groups and the variance between groups. In this research I used it to understand the relationship, which is there between the variables such as age, gender, race, types of schools, academic qualification against the variables such as GIS knowledge, effectiveness of GIS as teaching tool in geography, attitude of teachers etc. Also, I wanted to understand the views of the geography teachers on GIS, whether age, gender, race and teaching experience and types of schools where teachers are teaching have any influence on their views. If not, what could be the other underlining factors which are affecting the diffusion of GIS in high schools in the study area.

4.3.1 RESEARCH OBJECTIVE 1: TO EXAMINE TEACHERS' ATTITUDES TOWARDS THE INCLUSION OF GIS IN GEOGRAPHY AT THE FET PHASE

To achieve the first objective of this study, teachers were asked questions about their attitudes toward GIS. For the questionnaire survey, they had to indicate their level of agreement on eleven statements (see Table 4.6, Section F in Appendix A), and teachers were interviewed and had their lessons observed while teaching GIS topics. Each statement (See Table 4.6) was scored on a five-point Likert scale, with 1 representing strongly disagree and 5 representing strongly agree Also, descriptive statistics (frequency counts and percentages), Fisher's test, Wilcoxon tests and Kruskal-Wallis test statistics were used to analyse the data from 50 questionnaire and extracts from the 10 interviews were also used.

Attitudes of the geography teachers towards GIS

The findings revealed that teachers had a range of attitudes toward the incorporation of GIS into the geography curriculum, both positive and negative. This was revealed by the results from the interviews and the lesson observations, and the statistical testing of the questionnaire data done in this research. In the questionnaire instrument, teachers were given 10 statements that focused on GIS, in Section F of the questionnaire, as a way of determining teachers' attitudes towards the inclusion of GIS in the geography curriculum. Also, during the lesson observation and interviews (pre and post) with the 10 teachers, their attitudes about GIS inclusion in the geography curriculum were also noted. The major picture that emanated regarding the first objective was that as a cohort, the teachers had mixed attitudes (positive, indecisive and negative) about GIS teaching and its inclusion in the geography curriculum. The majority of the teachers interviewed were enthusiastic about incorporating GIS into the geography curriculum during the FET phase. Sixty percent (60%) of the 10 participants showed positive attitudes (n=6), while 30% (n=3) showed negative attitudes and 10% (n=1) was indecisive about the inclusion of GIS in geography curriculum (Table 4.6).

Table 4.6: Teachers' attitudes summary towards inclusion of GIS in the geography curriculum of the FET phase (data from lesson observations with 10 participants

School No. & types	Teacher	Responses indicating attitudes towards GIS inclusion in FET phase (quotes)	Attitudes		
			Positive	Indecisive	Negative
1 Public urban	Mr Van Wyk	*Yeah, I can say its fine as long as they don't expect the learners to go deep into GIS. We do not have stand-alone GIS lab. The only lab available is for those who are doing computers and the teachers concerned do not allow any other teacher to work in there. Even if I want to show my geography learners some digital geography maps on the computer, I cannot do so. The computer room is always under lock. If the school can provide us with a GIS lab at least we can learn one or two things on GIS and the learners can benefit a lot.*		Indecisive	
2 Private urban	Mr Tau	*It's a great idea because it prepares learners for university. I use GIS when I teach river systems when I talk about flooding and the need to avoid disasters by applying the concept of buffering. GIS technology is important when we want to demarcate where people should be resettled and when we want to evacuate people from the disaster areas. In this case I will overlay the topographical maps showing the rivers and the settlement map. The learners can visualise and suggest some solutions to the problems when they study the maps.*	Positive		
3 Public rural	Ms Fatima	*At times I have a good feeling it was not a good idea at all, because it's a difficult concept to teach this section, with limited resources is not easy. I need training in GIS.*			Negative
4 Public urban	Ms Mable	*Aa, I can say it's a good idea since there are lots of job opportunities available in this field. But it's difficult area I should say.*	Positive		
5 Public urban	Mr Robson	*It is the best idea because it opens the learners' minds and assists them in developing inquisitive minds.*	Positive		
6 Private urban	Mr Douglas	*I think is the best idea considering that everything in life is GIS. So, I think it is the best idea and it also helps the learners, you know, to have inquisitive minds and able to solve problems.*	Positive		
7 Public rural	Ms Letimia	*It was a good idea that GIS was introduced aaa…because we are living in the age of technology and GIS is one of them.*	Positive		

School No. & types	Teacher	Responses indicating attitudes towards GIS inclusion in FET phase (quotes)	Attitudes		
			Positive	Indecisive	Negative
8 Public rural	Mr Rua	*Umm, well, it's good, but learners are not learning much in this section, to be frank with you.*			Negative
9 public urban	Mr Ngubane	*Yeah, I can say it was not good…because we are struggling to teach this section. During my training there was no GIS modules being offered. We only did Physical geography, human geography, urban geography, Biogeography and many other subjects. GIS was introduced recently and it is posing a big challenge to me.*			Negative
10 Public rural	Ms Abigail	*Yeah, somehow, it was good, we will improve as time goes on, but…aa it's a big challenge. But GIS topics are difficult to teach because as you can see learners do not have enough resources. Most of the times they share textbooks and some of them- they do not come to school with their textbooks. The class is overcrowded as you can see and it is under resourced There is not internet/WIFI connectivity at this school. Even if I wish to download some of the useful GIS data and YouTube videos, I cannot able to do that.*	Positive		

It is clear from Table 4.6 that teachers at schools 2, 4, 5, 6, 7 and 10 felt that GIS inclusion in the geography syllabus was a good idea. There are different reasons which can contribute to the attitudes of teachers towards the inclusion of GIS in the geography curriculum.

Table 4.7 indicates the statements which were asked in the questionnaire to determine the attitudes of the teachers towards GIS inclusion in the geography curriculum. The percentage of each statement asked are also summarised on the table. According to Table 4.7, 62% and 30% of teachers strongly agreed and agreed, respectively, that GIS is an effective teaching tool that can be used in geography lessons, with only 6% neutral and 2% strongly disagreeing (item 1). This implies that the majority of teachers in the sample understood the value of GIS in the curriculum. Relating this finding to the teachers' perception of the technology's benefit in schools in other countries where similar studies had taken place, it confirms the previous studies findings (Gorder, 2008; Ferreira & Schulze, 2014). To improve GIS education in schools, the majority of teachers in the current study (43 percent strongly agreed and 56 percent agreed) said that classrooms should be provided with computers, a projector, and GIS software (see Table 4.7, item 2). Majority of the teachers (52% strongly agree and 38%

agreed) believed that GIS lessons support critical thinking and problem solving in learners with only 10% choosing to be neutral, (item 7).

Table 4.7: Teachers' attitude towards GIS inclusion in the geography curriculum (questionnaire data; n=50).

Statements		Participation Degree				
		Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly disagree (1)
1	GIS is an effective teaching tool that I can use in geography lessons.	62%	30%	6%	-	2%
2	Computers with the GIS software, projector are essential to have in teaching GIS in class.	43%	56%	1%	-	-
3	Geography teachers need training on how to teach and use GIS.	74%	24%	-	2%	-
4	The use of GIS in geography courses are required.	40%	32%	26%	2%	-
5	GIS supports learner-centred teaching and learning	40%	30%	30%	-	-
6	GIS concepts motivate learners to like geography more.	30%	30%	40%	-	-
7	GIS lessons support critical thinking and problem solving in learners.	52%	38%	10%	-	-
8	GIS teaching needs hands-on experience with a computer in the class.	26%	34%	40%	-	-
9	The teaching of GIS takes a lot of time to learn.	40%	36%	24%	-	-
10	GIS technology is hard to learn and to teach	38%	36%	26%	-	-

Responses on the time that it takes for a teacher to understand GIS content, the majority (76% made up of 40% who strongly agreed and 36% who agreed) were of the view that GIS takes much time to learn whereas 24% of participants chose to be neutral on this statement, (item 9). The following section discusses the findings in more detail.

Attitudes of teachers towards GIS by gender

Teachers' attitudes towards GIS were further examined using cross tabulation by gender to get a deep understanding of the relationships whether gender has an influence on the attitudes of teachers towards GIS inclusion in geography curriculum.

Table 4.8 shows the teachers' responses by gender from the questionnaire when they were asked whether they see GIS as an effective tool for teaching geography. The findings showed that the majority (56.25%) female teachers strongly agree, and 64.7% male teachers strongly agree that GIS is effective in teaching geography. However, 2% strongly disagreed with this statement, and 6% were neutral. Both male and female teachers in this research agreed that GIS is a good tool in teaching geography and showed a positive attitude (Table 4.8). Their attitude towards GIS is not determined by gender. The findings from the lesson observations and interviews also showed a similar result.

Table 4.8: Effectiveness of GIS for teaching geography, by gender (questionnaire data, n=50)

Crosstab							
			Effectiveness of GIS in teaching Geography				Total
			Strongly Disagree	Neutral	Agree	Strongly Agree	
Gender	Female	Count	0	1	6	9	16
		% of Total	0,0%	6.25%	37.5%	56.25%	100,0%
	Male	Count	1	2	9	22	34
		% of Total	2.94%	5.88%	26.47%	64.70%	100,0%
Total		Count	1	3	15	31	50
		% of Total	2.0%	6,0%	30,0%	62,0%	100,0%

This was revealed by Mr Rua during the interview when he was asked to rate the effectiveness of GIS as a teaching tool in geography. Mr Rua stated the following:

I use GIS when I teach river systems when I talk about flooding and the need to avoid disasters by applying the concept of buffering. GIS technology is important when we want to demarcate where people should be resettled and when we want to evacuate people from the disaster areas. In this case I will overlay the topographical maps showing the rivers and the settlement map. The learners can visualise and suggest some solutions to the problems when they study the maps.

Ms Letimia stated the following:

It was a good idea that GIS was introduced aaa…because we are living in the age of technology.

Mr Robson explained that:

It is the best idea because it opens the learners' minds and assists them in developing inquisitive minds and able to solve problems.

The three extracts above showed that the teachers had positive attitudes towards GIS. During the lesson observation and interviews with Mr Rua when he was teaching different types of data: Raster and Vector data in grade 11, he was very enthusiastic and motivated in his approach to the topic. He showed a positive attitude to GIS and he even encouraged his class to select GIS in tertiary studies so that they can become GIS specialists. Ms Letimia also showed positive attitudes towards GIS in her responses when she was asked about the effectiveness of GIS as a teaching tool (see Table 4.6). Also, Ms Letimia and Mr Robson showed positive attitudes when they were asked about the effectiveness and inclusion of GIS.

Results from the interviews, lesson observations and questionnaires showed that the attitudes of the teachers towards GIS inclusion have no correlation with their gender. Both females and males demonstrated positivity with the exception of Mr Ngubane and Ms Fatima who showed negative attitudes when they were asked about the effectiveness of GIS as a teaching tool. Mr Ngubane could not see it as an effective tool because he did not have exposure to the GIS technology during his training. The following extract showed his response.

During my training there was no GIS modules being offered. We only did Physical geography, human geography, urban geography, Biogeography and many other subjects. GIS was introduced recently, and it is posing a big challenge to me.

Also, Ms Fatima explains the following:

At times I have a good feeling it was not a good idea at all, because it's a difficult concept to teach this section, with limited resources is not easy. I need training in GIS.

Ms Fatima felt that it was not a good idea that GIS was introduced into the geography curriculum. She stated that GIS is a difficult concept to teach. It is clear from Ms Fatima that her negativity about GIS is based on its difficult to learn and to teach and lack of resources. Teachers have a negative attitude towards a subject due to various reasons (Omolara, 2015). In the case of Ms Fatima, her negativity towards GIS is based on a lack of content knowledge in GIS. She bemoaned her lack of knowledge and limited resources at the school where she teaches. The environment and lack of adequate resources may lead the teacher to have a negative attitude towards the subject they teach (Demirci & Karaburun, 2009; Omolara, 2015; Akinyemi, 2015).

Overall, only 2% strongly disagreed and 6% were neutral from the questionnaire survey. Those who disagreed on its effectiveness and remained neutral, were lacking exposure to the new technology of GIS as Mr Ngubane explicitly explained the reason why he was not interested in GIS. For instance, data from the interviews revealed that some teachers were not seeing GIS as an effective tool in teaching geography topics.

Although GIS has been introduced in many institutions of higher education such as universities and teaching colleges, in many African countries including South Africa, some colleges and universities do not offer it in-service teacher training. Furthermore, despite advancements in GIS education, many African learning institutions of higher education continue to face challenges in its development and application as a teaching and learning tool (Mzuza & van der Westhuizen, 2019). In their study, the authors identified several major issues, including the lack of GIS education in secondary school curricula, a scarcity of experienced teachers to teach GIS, a lack of knowledge and technical expertise, teachers' unwillingness to change their teaching styles, and a lack of funds to purchase GIS software, computers, lack of knowledge and skills to use open-sources such as QGIS and other resources (Mzuza & van der Westhuizen, 2019). Thus, GIS education has a host of challenges to its adoption and use in SA schools.

GIS software is needed to teach GIS in high school

The participants from all the three instruments used in this research were also asked whether they felt that GIS software was needed in the classroom in order to teach GIS. The findings on this question from the questionnaire are indicated on Table 4.9.

Table 4.9: GIS software needed to teach GIS in high schools, by gender, cross-tabulation (questionnaire data, n=50)

Crosstab						
			GIS software needed to teach GIS			Total
			Neutral	Agree	Strongly Agree	
Gender	Female	Count	0	10	6	16
		% of Total	0,0%	62.5%	37.5%	100,0%
	Male	Count	5	18	11	34
		% of Total	14.7%	52.9%	32.35%	100,0%
Total		Count	5	28	17	50
		% of Total	10,0%	56,0%	34,0%	100,0%

Female teachers (62.5%) and male teachers (52.9%) agreed that GIS software was needed to teach GIS at high schools. This further showed their passivity on GIS. The fact that they know the need for GIS software indicates that the teachers are teaching GIS and know the requirements to effectively teach it. Only (14.7%), of male teachers were neutral. It is possible that the participants were not aware that GIS software was needed to teach GIS since GIS was introduced into the geography curriculum a decade ago. Also, it can mean that these teachers (10% of the total questionnaire sample) were not sure whether they needed GIS software to teach GIS topics, and this is of great concern because it could indicate that they were not teaching GIS or that they lack knowledge and skill to use the available open-source software and they were thus unable to comment.

This finding corresponds with the data gathered from the interviews, where the teachers suggested that GIS software, such as ArcMap or QGIS, and computers are needed in geography classrooms. It was advanced that the availability of computers and GIS software would greatly assist teachers, especially when they want to demonstrate certain content and skills to the learners. The following extracts from the interviews attested to this effect. Mr van Wyk explained when he was asked about the availability of GIS equipment at his school. Mr van Wyk explained the following:

We do not have stand-alone GIS lab. The only lab available is for those who are doing computers and the teachers concerned do not allow any other teacher to work in there. Even if I want to show my geography learners some digital geography maps on the computer, I cannot do so. The computer room is always under lock. If the school can provide us with a GIS lab at least we can learn one or two things on GIS and the learners can benefit a lot.

Mr van Wyk believed that he needed access to a separate GIS lab because the computer lab was being monopolised by the computer teacher and the teachers in other disciplines had no access to computers and thus no GIS software uploaded on them. He further asserted that if the GIS lab was provided and computers installed with GIS software, teachers can be able to learn and be in a better position to assist the learners learn GIS and improve his attitude about GIS inclusion in the geography curriculum. Their lack of interest and enthusiasm in some of the topics of GIS has greatly resulted in a poor attitude towards teaching and thus it can affect learners' performance (Omolara, 2015; Akinyemi, 2015). Resource needs resulted in a tendency to demoralise some of the teachers in GIS teaching.

These findings resonate very well with the findings of the 2019-2020 Department of Education report in Northern Cape province. The report revealed that there were some schools where learners were not attempting questions in GIS section at all. Also, a 2018-2019 Department of Education report in geography in Eastern Cape province revealed that learners have mastered GIS concepts but lack the ability to apply these concepts to deal with real life situations. The report revealed that Questions 4.1.2 in 2019 Matric geography paper 2 (relevance of vector using vector data) and Q4.2.2 (application of scale to a geographical problem) were poorly done because the learners failed to understand what the question required them to do. The report alluded that most learners lacked basic content knowledge in GIS. The 2019 geography report in Northern Cape indicated the same sentiments, a year earlier, as stated above. Most of the learners failed map work and the GIS section in paper 2 of the matric examination (exit examination in secondary school).

GIS training

The attitudes of the teachers were also tested on GIS training (Table 4.10 and on section E, questions 1-9 (see Appendix A). The majority of the participants, 81.25%, female teachers and 70.58% male teachers, who filled the questionnaire, (see Table 4.10), were strongly in agreement that teachers need training in GIS in order to teach topics in GIS effectively. Cumulatively, 98% of the teachers agreed that indeed there is a need for GIS training. Only 2% disagreed (see Table 4.10). The teachers surveyed in the questionnaire showed a positive attitude towards training of GIS.

Table 4.10: Teachers need training in GIS, by gender, cross-tabulation (questionnaire data, n=50)

Crosstab

			Teachers need GIS training			
			Disagree	Agree	Strongly Agree	Total
Gender	Female	Count	0	3	13	16
		% of Total	0,0%	18.75%	81.25%	100,0%
	Male	Count	1	9	24	34
		% of Total	2.94%	26.47%	70.58%	100,0%
Total		Count	1	12	37	50
		% of Total	2,0%	24,0%	74,0%	100,0%

This view of the value of training was also shared by the teachers whom I interviewed. During the post lesson observation interviews the teachers stressed that they need training in GIS. If the teachers are trained on how to use and teach GIS in geography this can improve their attitudes towards the technology, and they can do more in helping the learner to line GIS and to improve their pass rate in this section. The following are the extracts from the interviews:

Ms Fatima:

Her response to the question, have you been able to implement the teaching of GIS with ease in your school? shows her inability to effectively teach GIS. She responded by saying:

No, as I said, this is a challenging area, it's difficult. I don't have the resources and much skills to teach this concept. I need training in GIS.

Also, when Ms Fatima was asked about the adequacy of the training she had received in as far as GIS is concerned, her response showed that she was frustrated by the topics contained within the GIS section. For example, she gave the following explanation:

No, yeah, I forgot all I learnt at the workshop, but the session was good. The training I got was not well grounded. I did not learn much and were left to go and struggle alone with the learners. It is difficult.

Ms Fatima shows how lack of GIS content knowledge can demotivate the teachers in a big way. During the lesson observations and interview it was found that geography teachers did not show deep interest in teaching GIS, and it negatively affected their attitudes.

Mr Ngubane stated the following:

I need training in GIS because when I did my training long time ago there was no GIS thing. I am struggling to understand this concept of GIS. I need more training and resources.

Also, results from the lesson observation confirmed this dire need for training on how to teach GIS in schools. During the lesson observation it was found that teachers were struggling to explain key concepts in GIS. There was no constructive teaching taking place during the lesson observations and this would have led to superficial learning which I observed in some classes. It was evident from lesson observation that geography teachers were not always ready to teach topics of GIS to their learners. This is supported by the difficulties I faced when I was trying to schedule meetings and lesson observations in GIS lessons. Most of the teachers kept on postponing and I was unable to undertake the lesson observations I was expecting to do. I eventually managed to observe one lesson per teacher than the two lesson observations I had initially scheduled.

There are 2 critical aspects which teachers alluded to in the questionnaires and in the interviews: they lack GIS content knowledge, and they lack pedagogical content knowledge on how to teach GIS and this negatively affected their attitudes towards GIS. Although the majority of the teachers in the questionnaires indicated the importance of GIS in geography, their attitudes during the lesson observations were contrary to their understanding of its value.

GIS technology is difficult to learn and to teach

The teachers' attitudes were also sought on whether GIS technology is difficulty or easy to understand and to teach. GIS technology, according to the teachers, was difficult to understand and use (Table 4.11). The overwhelming majority of participants (questionnaire data -76.5%) reported that GIS technology was difficult to teach and understand for teachers; 23.5% were neutral. The data from the interviews with teachers also confirmed the notion that GIS was regarded as difficult. Teachers believed that GIS was difficult to understand, and that they needed more time to learn about it in order to teach it. This has relevance for the reasons why teachers have negative attitudes towards GIS.

Table 4.11: GIS technology is difficult to teach and to learn, by gender, cross-tabulation (questionnaire data, n=50)

Crosstab						
			GIS technology is hard to learn and to teach			Total
			Neutral	Agree	Strongly Agree	
Gender	Female	Count	5	4	7	16
		% of Total	31.25%	25,0%	43.75%	100,0%
	Male	Count	8	14	12	34
		% of Total	23.5%	41.17%	35.29%	100,0%
Total		Count	13	18	19	50
		% of Total	26,0%	36,0%	38,0%	100,0%

Data from the interviews supported this finding. The extracts from the interview with Ms Abigal who teaches at a rural school and Mr Ngubane who teaches at a township school, when asked whether they enjoyed teaching GIS to learners, indicated their classroom experience: Ms Abigal explained that:

GIS topics are difficult to teach because as you can see learners do not have enough resources. Most of the times they share textbooks and some of them- they do not come to school with their textbooks. The class is overcrowded as you can see, and it is under resourced There is not internet/WIFI connectivity at this school. Even if I wish to download some of the useful GIS data and YouTube videos, I cannot be able to do that.

Mr Ngubane stated that:

I tried my level best to follow what is in the textbook, but still these GIS topics are difficult to teach because I did not have the opportunity to be taught GIS when I was doing my degree training long time ago. GIS is new to me and I am struggling in this section.

Mr van Wyk explained:

GIS topics are difficult to teach without a GIS lab. I tried to be creative but still the learners don't get this section alright

Mr Douglas at School 6 stated that regarding the difficulty of GIS:

GIS topics lack content and activities in the Platinum Geography textbook I am was using, I find it challenging to teach these topics. I think it was going to be much easier if I had other textbooks and a computer with GIS software. I would be able to show some of the concepts and make my explanation and teaching much easier.

Mr Tau at School 2 stated that:

I don't understand some of the concepts in GIS, they are difficult to learn and to teach without a GIS lab.

The above responses show that the teachers had negative attitudes towards GIS for various reasons. One of the reasons the teachers repeatedly were mentioning is that GIS is a difficult technological innovation to teach, the teachers were struggling to teach topics in GIS due to lack of access to a laboratory, inadequate instructional materials and teachers' lack of GIS content knowledge which then affected their teaching methods of GIS.

Mr Ngubane was not confident about what he was doing during the lesson observation and, therefore, his behaviour in the classroom was shaped by his belief that the topics of GIS were difficult, and this affected his attitude towards GIS. Also, both Mr van Wyk and Mr Douglas showed some difficulties in teaching some topics in GIS.

Mr Douglass who was observed teaching: Data standardisation, data sharing and data security in grade 12, had numerous difficulties in explaining some of the concepts he was teaching. Mr Douglas bemoaned the lack of content and activities in the Platinum Grade 12 geography textbook he was using, which he depended upon. For instance, he mentioned that there was only one activity in the textbook which he felt had few questions he can use and give to the learners to make them understand the concepts of GIS he was teaching. He further mentioned that they do not have computers with GIS software which he can use to teach some of the topics in GIS in the school. Mr Douglas was very aware that GIS teaching needs the availability of computers and GIS software. From the observation, it was evident that Mr Douglas was trying to make an effort to compensate for the shortage of the resources in the classroom. He showed some of the images of the institutions and people who can share the GIS data. His main concern was that there were not enough resources in the school and content in the geography textbook that he could use to explain the concepts he was teaching to the learners.

Attitude of teachers by age

Teachers' attitudes towards GIS were further examined using cross tabulation by age. The main findings were that most of the participants from the questionnaire (75%) aged 26-29 years strongly agreed that GIS is an effective teaching tool in geography (See Table 4.12below). Also, findings from the interviews and lesson observation showed relatively young teachers had a positive attitude towards GIS. Only 40% (n=4) aged over 50 years showed negative attitude and 60% (n=6) aged between 26-49 years showed positive attitude towards GIS.

Table 4.12: GIS technology is an effective teaching tool in geography, cross-tabulation by age (questionnaire data, n=50)

Crosstab							
			GIS as an effective tool in teaching Geography				Total
			Strongly Disagree	Neutral	Agree	Strongly Agree	
Age	26-29 Years	Count	0	0	3	9	12
		% of Total	0,0%	0,0%	25,0%	75,0%	100,0%
	30-39 Years	Count	0	1	7	8	16
		% of Total	0,0%	6.25%	43.75%	50,0%	100,0%
	40-49 Years	Count	0	1	4	12	17
		% of Total	0,0%	5.89%	23.52%	70.59%	100,0%
	≥50Years	Count	1	1	1	2	5
		% of Total	20,0%	20,0%	20,0%	40,0%	100,0%
Total		Count	1	3	15	31	50
		% of Total	2,0%	6,0%	30,0%	62,0%	100,0%

Mr Ngubane who was over 50 years of age had negative attitudes about GIS and he explained the following when he was asked what he felt about GIS inclusion in the geography curriculum.

Yeah, I can say it was not good…because we are struggling to teach this section. I did my teacher training at university long time ago. During my training there was no GIS module being *offered. We only did Physical geography, human geography, urban geography, Biogeography and many other subjects. GIS was introduced recently, and it is posing a big challenge to me*

Also, Mr van Wyk (over 50 years of age) showed some a mixed attitude:

Yeah, I can say its fine as long as they don't expect the learners to go deep into GIS. GIS topics are difficult to teach without a GIS lab. I tried to be creative but still the learners don't get this section alright.

Ms Fatima (over 50 years of age)

At times I have a good feeling it was not a good idea at all, because it's a difficult concept to teach this section, with limited resources is not easy. As you can see at this school there is no electricity and internet connectivity. Even if I want to try to download QGIS, there is no internet. It is difficulty.

From the extracts above, Mr Ngubane who was 50 years of age who teaches at a township school showed a negative attitude towards the inclusion of GIS in the geography curriculum because according to him he finds GIS challenging since he has no training and thus no knowledge of GIS from his university education. In the same vein, Ms Fatima who teaches in a rural high school, who was 50 years of age, also had a feeling that GIS inclusion in the geography curriculum was not a good idea because she finds GIS difficult to teach and she complained about the lack of resources as one of the reasons she had a negative attitude towards teaching GIS topics. His school had no electricity and internet connectivity, and this made it very difficult for her to use a laptop and downloading QGIS. Also, Mr van Wyk who was over 50 years of age, showed indecisiveness about GIS inclusion in the geography curriculum (see Table 4.6). All three extracts from the interview showed that there is an association between age and GIS technology inclusion in the geography curriculum and the attitudes of relatively older teachers were negative. Older teachers had a negative attitude about GIS. Their negativity emanated from a number of reasons. The findings from this research showed that the teachers do not enjoy teaching GIS topics and they do not enjoy associating themselves with the new technology. Therefore, they teach learners out of necessity to adhere to the requirements of the curriculum and not out of passion and resultantly, what they teach is reluctantly carried out. The teachers were also defensive in their attitude because they were dissatisfied. Such teachers, the literature reveals, are likely to express negative attitudes towards teaching and learning (Omolara, 2015).

Contrary, relatively younger teachers showed positive attitudes. Young teachers, millennials, grow up in a world with rapidly improving technology hence it is understandable that they displayed a positive attitude towards GIS, a new technological innovation included in the subject Geography. This is also because they are recently graduated and were trained in GIS when they were in colleges and universities.

The following extracts support this view.

Ms Letimia (aged 26-29 years) explained that:

I had the opportunity to major in Geography, Mathematics and Technology when I was doing my training. In Geography courses, we did Introduction to GIS as a module. That module gave me the fundamental foundation to learn GIS and have the content knowledge which is required in the FET phase Geography.

Mr Douglas (26-29 years) stated that:

I think it's the best idea considering that everything in life is GIS. So, I think it is the best idea and it also helps the learners, you know, to have inquisitive minds. I enjoy teaching GIS in my classes because I can apply what I had learned at university during my training. I also have the opportunity to show the learners that they can use their cell phones to do some of the tasks. For instance, they can take a picture using their smart phones and be able to analyse resolution and they can also use their cell phones to determine the GPS of a place. I think what is needed is to identify the gadgets available and use them to achieve what one wants to achieve in the lesson.

Ms Letimia and Mr Douglas's responses showed that these teachers have positive attitudes and are excited about GIS. Mr Douglas raised a very important issue in his response, that he enjoyed teaching GIS and it helped him to practice what he learned at university and that one has to be innovative and creative in identifying the gadgets which are readily available in the class to use in GIS teaching. His articulations show that he was creative in his lessons on GIS, planning his lessons with available technology to teach GIS.

This view was further attested to by the findings from the teachers I interviewed and observed teaching GIS topics. Young teachers strongly agreed that GIS was an effective teaching tool in teaching geography in comparison to relatively older teachers. Mr Rua (26-29 years) was able to apply GIS in some of the topics he was teaching than Mr van Wyk (over 50 years of age) who was teaching Remote Sensing to grade 12, who did not make any reference to GIS when he was teaching other topics. Also, the extract from the interviews confirms this.

For example, Mr Ngubane (over 50 years of age who teachers at township school) stated the following about the effectiveness of GIS:

GIS is posing a big challenge to me and I don't see it as an effective teaching tool in geography. As you can see, (showing the textbook he was using) there are nothing much written about GIS in this textbook. I struggled to find extra reading material for my learners.

Ms Fatima (over 50 years of age) who teaches in a rural school also commented on the effectiveness of GIS:

I don't know whether it is effective in teaching geography because I have never used GIS software. I don't have the resources which I can use to add what is in the textbooks I am using. Even if I get GIS data from somewhere else, I don't know how to use it or explain it to the learners because I don't know much about GIS myself and also there are no computers and GIS software.

I further probed her whether she had heard about free downloaded QGIS. She responded by saying:

Yes, I heard about QGIS, but I have never used it or downloaded because I don't have a laptop and I don't know how to do it. Even if I have a laptop, I cannot be able to use it in this large class. There is no electricity and internet connectivity at this school.

Mr van Wyk (over 50 years of age) explained the effectiveness of GIS:

I have never changed the way I teach geography. I apply the same teaching methods as I have been doing over the year. I am not seeing the difference because I don't have stand-alone GIS lab where I can try to learn and see whether it is an effective tool.

From the extracts above, Mr Ngubane who is over 50 years of age cannot see the effectiveness of GIS as a teaching tool in his class. In the same vein, Ms Fatima who is also over 50 years of age, was not sure whether GIS is effective or not because she had never used the GIS tool. She complained about the lack of electricity and internet connectivity in her rural school. Also, Mr van Wyk who is over 50 years of age said that he applied the same teaching methods when teaching other topics in geography. He further stated that he is not seeing its effectiveness because there is no stand-alone GIS lab where he can learn and take his learners to visit.

Only relatively young teachers see GIS as an effective tool in teaching geography. The following extracts support this view.

Ms Letimia (aged 26-29) stated that:

GIS is an effective tool in geography. I used it more often when I teach other topics in geography. I applied it in population studies and economic geography topics. For example, I use GIS when I teach population distribution and factors which affect population distribution.

Mr Douglas (26-29 years) said:

GIS is effective in teaching geography topics such as volcanoes, rivers and economic geography. I also have the opportunity to show the learners that they can use their cell phones to do some of the tasks. For instance, they can take a picture using their smart phones and be able to analyse resolution and they can also use their cell phones to determine the GPS of a place.

All the above extracts showed that GIS technology use in the classroom in other themes of geography is age selective. Relatively younger teachers see its effectiveness and enjoy teaching the topics in GIS more than older teachers as they can teach their learners to use cell phones to learn about GIS.

GIS software is needed to teach GIS in high schools

All the teachers (100%) aged 26-29 agreed that GIS software was needed to teach GIS topics (see Table 4.13).

Table 4.13: GIS software is needed to teach geography, cross-tabulation by age (questionnaire data, n=50)

Crosstab						
			GIS software needed to teach GIS topics			Total
			Neutral	Agree	Strongly Agree	
Age	26-29 Years	Count	0	7	5	12
		% of Total	0,0%	58.33%	41.67%	100,0%
	30-39 Years	Count	3	10	3	16
		% of Total	18.75%	62.5%	18.75%	100,0%
	40-49 Years	Count	2	6	9	17
		% of Total	11.76%	35.29%	52.94%	100,0%
	≥50Years	Count	0	5	0	5
		% of Total	0,0%	100,0%	0,0%	100,0%
Total		Count	5	28	17	50
		% of Total	10,0%	56,0%	34,0%	100,0%

The results also revealed that participants aged between 30-39 (81%) believed that GIS software is needed to teach GIS topics. However, 18.75% of this age group remained neutral on this statement. This could be due to not knowing much about GIS and they could therefore not able to comment or to give an appropriate opinion whether GIS software is needed to teach GIS topics in the geography curriculum. The findings from the lesson observations also confirmed that there were no GIS laboratories and software in most of the schools which I visited, and this could one of the reasons why the teachers had negative attitudes towards GIS. Even though some teachers were using their personal laptops to download QGIS, for instance Mr Tau (40-49 of age) at school 2, had QGIS on his personal laptop. He complained about internet connectivity at the school. He stated that the internet was very poor and that it poses a big challenge and therefore he could not make adequate use of QGIS in the lessons. These environmental challenges negatively affect the commitment and positive attitudes some teachers might have if these challenges are not met. Learners always have better assimilation of the subject if teachers show charming interests in their subjects (Omolara, 2015).

Attitudes of teachers according to the school type

Since the Likert scale (ordinal scale) was used to measure items that addressed GIS as a teaching tool, the nonparametric Wilcoxon's W tests was used to compare the effects of the GIS inclusion in the teaching of geography according to the type of school. The results presented in Table 4.14 show that there was a strong belief in GIS as an effective teaching tool that can be used in geography lessons. The percentages of those who showed positive attitudes in GIS as an effective teaching tool in geography was high for both teachers in private schools (83%) and public schools (93%) and the (2%) of those who strongly disagree was not significantly different (W=107.0, p-value=0.109). This means that private and public-school teachers surveyed in this research were overwhelmingly convinced that GIS was indeed an effective teaching tool for geography. The findings from the questionnaire also showed that the teachers' attitudes towards GIS were not influenced by the type of schools where teachers were located. However, 16.7% of teachers in private schools strongly disagreed with the view and it could be that the teachers lacked the exposure to GIS technology. The findings from the interviews and lesson observations correspond with the findings from the questionnaire survey.

Table 4.14: Cross-tabulations of GIS as a teaching tool, by type of school (questionnaire data, n=50)

GIS as a teaching tool		**Type of school**		**Wilcoxon's-W test**	
		Private	Public	W	p-value
GIS is an effective teaching tool that I can use in geography lessons	Strongly disagree	1	0		
	Neutral	0	3	107.0	0.109
	Agree	3	12		
	Strongly agree	2	29	**No Significant difference in mean ranks**	
	%agree/strongly agree	83%	93%		
	Mean rank	17.83	26.55		
Computers with the GIS software, projector are essential to have in teaching GIS in class	Neutral	0	5		
	Agree	3	25	1090.5	0.228
	Strongly agree	3	14		
	%agree/strongly agree	100%	89%	**No Significant difference in mean ranks**	
	Mean rank	30.75	24.78		
Geography teachers need GIS training	Disagree	1	0		
	Agree	1	11	136.5	0.518
	Strongly agree	4	33		
	%agree/strongly agree	83%	100%	**No Significant difference in mean ranks**	
	Mean rank	22.75	25.88		
	Disagree	1	0		

The use of GIS in Geography courses is required	Neutral	2	11	120.5	0.303
	Agree	1	15		
	Strongly agree	2	18		
	%agree/strongly agree	50%	75%	**No Significant difference in mean ranks**	
	Mean rank	20.08	26.24		

The results also showed that most participants believed that computers with GIS software and a projector are essential to have in the teaching of GIS in classes (100% of private and 89% of public-school participants). Most participants also recognised the need for geography teachers to undergo GIS training (83% of private and 100% of public-school participants).

In general, both private and public-school teachers supported the inclusion of GIS in the geography curriculum, and there was no significant difference in attitudes between the two types of schools (p-values>0.05). Findings from lesson observations and interview on attitudes of teachers towards GIS inclusion in geography curriculum by type of school showed almost similar result. Most of the teachers in the private (independent) and former C model schools showed positive attitudes and efforts in using GIS. For instance, Mr Tau at school 2 which is a former C model school had installed QGIS software on his personal laptop. Also, Mr Robson who teaches in one of the private schools, had similarly downloaded QGIS onto his personal laptop.

When Mr Rua (aged 26-29) who teaches at a rural school, was asked whether he enjoyed teaching GIS to learners, he gave a response that reflected a positive attitude but a negative view of the extent of learning unfolding amongst his learners. He explained that:

Umm, well, it's good but learners are not learning much in this section, to be frank with you. As you can see there is no electricity and internet connectivity at this school. I wish if the school can buy us some data bundles/internet routers so that we can use internet to teach some of the concepts, not in GIS only but many geography topics and other subjects which can benefit from the availability of electricity and WiFi at this school.

The explanation given by Mr Rua showed that he was a person who was knowledgeable about modern technology, but the environment in which he found himself in an under resourced school stifled his development and impacted on the diffusion of GIS. Also, when he was asked about his subject specialisation at the university, he revealed that he majored in geography, mathematics and technology. This response showed that Mr Rua was very knowledgeable about GIS and he had a positive attitude towards it. He was also not convinced that his learners were achieving the educational outcomes for this section. This was also evidenced during lesson observation. Mr Rua showed much enthusiasm when he was teaching GIS topics. During the lesson delivery, I observed that the learners were not participating during the lesson. Learners who were sitting at back rows in the classroom were busy doing work in other subjects during Mr Rua's lesson. Only a few learners who were sitting in the front rows of the classroom were learning and participating during the lesson. Mr Rua did not move around in the classroom and check if every learner was following his lesson and learning the concepts of Raster and Vector data which he was teaching during the lesson. In some instances, during the lesson, there was total chaos as learners were fighting over few textbooks which were being distributed during the lesson. In this lesson, I also observed that there was a lack of reading material and Mr Rua did not make an effort to borrow reading materials for the learners who did not have textbooks.

4.3.2 RESEARCH OBJECTIVE 2: TO EXAMINE TEACHERS' VIEWS ABOUT GIS TEACHING IN GEOGRAPHY IN THE FET PHASE

This section considered the responses of participants to the second research question, which reads: What are the teachers' views about GIS in geography in the FET curriculum? To understand the views of the teachers on this research question, the participants were asked a number of questions. The results from the three tools used in this study are discussed in the following section.

Availability of computing facilities

This section starts with an examination of the context of the schools and their physical infrastructure for teaching GIS which sets the backdrop for teachers' views that are expressed. Table 4.15 showed the responses given by the geography teachers regarding physical facilities available for GIS. In order to compare the availability of computing facilities between private (independent) and public schools, cross-tabulations of facility availability variables and type of school were done. This background check was necessary because it will have an influence on the views of the teachers teaching GIS in the schools. In order to test for independence between type of school and facility availability, which were both nominal variables, the Fisher's exact test was used. The Fisher's exact test is more appropriate over the asymptotic Chi-square test when dealing with small samples, as was the case in this study, where some of the cells of the contingency table (cross-table) had frequencies less than five.

The participants were asked to indicate the availability of physical facilities relating to GIS teaching. Only 17% of private school respondents indicated that they had a computer lab while 11% of public-school respondents said they had one. Thus, most surveyed schools did not have access to a computer laboratory for GIS. Table 4.15 indicated the test of association between the variable type of school (private/public) and availability of a computer lab in schools. The hypotheses were formulated as follows:

H0: There is no association between the type of school and availability of computer facilities

H1: There is an association between the type of school and the availability of computer facilities

On the test of association between the availability of computer lab and school type, the p-value (0.556) from the Fisher's exact test is greater than the significance level (0.05. We fail to reject the null hypothesis and conclude that the availability of a computer laboratory has nothing to do with the type of school, but this could be because many disadvantaged schools are sponsored a computer laboratory by industrial partners as part of their social responsibility.

The other results reported in Table 4.15 are based on questions investigating the availability of GIS software. All the research participants indicated that they had neither GIS software nor computers in their geography classes. There were no significant differences between private and public schools in relation to an internet connection in geography classrooms (Fisher's exact test p-value = 0.621). Neither of the two types of schools had GIS software nor computers for teaching geography classes. Teachers' views from both public and private schools agreed that there were no marked differences with regard to tested variables (Table 4.15). On items ii and iii on Table 4.15, participants did not respond and therefore there was no test which was done on them.

In summary, the Fisher's exact tests of association in Table 4.15 indicated that there is no relationship between the type of school and the availability of computing facilities as evidenced by the non-significant associations in the items tested.

Table 4.15: Cross-tabulations of Availability of computing facilities by type of school. (Questionnaire data, n=50)

		Type of school		Fisher's exact test
		Private	Public	p-value
Is there a computer lab in your school?	Yes	1	5	
	No	5	39	0.556
	% yes	17%	11%	Not significant
Do you have a GIS software?	Yes	0	0	
	No	6	44	-
	% yes	0%	0%	
	Yes	0	0	

Do you have a computer in your geography class for teaching	No	6	44	-
	% yes	0%	0%	
Do you have an internet connection in your geography classroom?	Yes	2	10	
	No	4	34	0.621
	% yes	33%	23%	Not significant

Knowledge of GIS software, by type of school

There were eleven items that measured the use and knowledge of GIS software as presented in Table 4.16below. The results in Table 4.16 showed the cross tabulation of items measuring the knowledge of GIS software by type of school. This was done so that it can be evaluated if there was uniformity in the knowledge of GIS software across private and public schools. The Fisher's exact test was used to evaluate the association between GIS knowledge and type of school. The Fisher's exact test, which computes the p-values directly, was used since the data had low frequencies in some cells (<5) which means that the use of the chi-square test would not be valid. The test of association between the variable type of school (private/public) and knowledge of GIS software hypotheses were formulated as follows:

H0: There is no association between the type of school and knowledge of GIS software.

H1: There is an association between the type of school and knowledge of GIS software.

The results in Table 4.16 showed that there were very few of the research participants that had ever used GIS software before, that is, 17% in private schools and 11% in public schools. On the test of association between knowledge of GIS software and school type, the p-value (0.556) from the Fisher's exact test is greater than the significance level (0.05). We fail to reject the null hypothesis and conclude that knowledge of GIS software has nothing to do with the type of school. This implies that the knowledge of GIS software amongst teachers across all types of schools is generally poor and that teachers will need training on GIS software, which is one of the topics in the CAPS.

Table 4.16: Cross-tabulations of Knowledge of GIS software by type of school (questionnaire data, n=50)

Knowledge of GIS software		**Type of school**		**Fisher's exact test**
		Private	**Public**	p-value
Have ever used the GIS software before?	Yes	1	5	
	No	5	39	0.556
	% yes	17%	11%	Not significant
	Yes	0	0	
	No	6	44	-

Have ever used GIS software before in your geography lesson with learners?	% yes	0%	0%	
Do you know exactly where to get help when you want to gain more knowledge and experience with GIS?	Yes	2	14	
	No	4	30	1.000
	% yes	33%	32%	Not significant
Do you think you were provided with sufficient knowledge, skills and materials on GIS by the DoE?	Yes	1	0	
	No	5	44	0.120
	% yes	17%	0%	Not significant
Have you been able to implement the teaching of GIS with ease in your school?	Yes	2	0	
	No	4	44	0.012
	% yes	33%	0%	Significant
How do you rate your GIS knowledge?	Weak	3	12	
	Fair	2	26	0.391
	Good	1 (17%)	6 (14%)	Not significant
Do you think geography lesson will benefits from GIS?	Yes	5	35	
	No	1	9	1.000
	% yes	83%	80%	Not significant
Knowledge about GIS	Weak	0	2	
	Fair	6	36	1.000
	Good	0	6	Not significant
Have ever received any training in GIS?	Yes	2	10	
	No	4	34	0.621
	% yes	33%	23%	Not significant
Was the training adequate?	Yes	2	6	
	No	4	38	0.026
	% yes	33%	14%	Significant
Who train you?	DoE	5	38	43
	University/college	1	4	0.0616
	Self	0	2	Not significant

On whether the respondents knew where to get help in order to gain more knowledge and experience with GIS, only 33% from private schools and 32% from public schools answered in the affirmative and the two percentages are not significantly different (p-value=1.000). Only 17% of participants from private schools indicated that they were provided with sufficient knowledge, skills and materials on GIS by the DoE while no one from public school thought so and the two percentages were not significantly different (p-value 0.120) to influence the view of the teachers.

Thirty-three percent (33%) of private school participants indicated that they have been able to implement the teaching of GIS with ease in their schools while none from public schools indicated the same. The two types of schools significantly differ on this matter (p-value=0.012) which means that private schools perform significantly better than public schools in matters of implementation of the teaching of GIS.

When asked to rate their GIS knowledge, only 17% of those from private schools gave themselves a rating of "Good" while 14% from public schools gave a similar rating. The two ratings are not significantly different (p-value=0.391). These low ratings indicate that there was still teacher professional development needed to upgrade participants' knowledge of GIS. Despite the low levels of GIS knowledge most of the participants from private schools (83%) and public schools (80%) were of the view that geography lessons will benefit from GIS. Only a small percentage of participants from private schools (33%) and public schools (23%) had received any training in GIS, and very few were of the view that such training was adequate (33% for private and 14% for public schools). Most of the training for both private and public schools was offered by the DBE.

In general, the results showed that the type of school did not have much influence on the way the teachers' view GIS on most items addressing the knowledge of GIS software, except for only two items in which teachers from private schools held a different view and understanding of GIS than teachers from public schools.

Geography teachers' views towards GIS inclusion in the geography curriculum by age

Teachers' views on GIS inclusion in the geography curriculum were also measured against teachers' age and GIS as an effective teaching tool in geography to see whether there was an association. A Likert scale was used to measure items that address GIS as a teaching tool. The t-tests were used to compare two groups and Analysis of variance tests (ANOVA) were used to compare more than two groups in the analyses that follow. The test of association between the variable age and GIS as effective teaching tool and hypotheses were formulated as follows:

H0: There is no association between the teachers' age and GIS effectiveness as teaching tool in geography.

H1: There is an association between teachers' age and GIS effectiveness as a teaching tool in geography.

On the test of association between the effectiveness of GIS as a teaching tool and teachers' age the p-value (0.213) from the Kruskal-Wallis Test is greater than the significance level

(0.05). We fail to reject the null hypothesis and conclude that the effectiveness of GIS as a tool has nothing to do with the teachers' age which is an unusual finding.

GIS as an effective teaching tool that I can use in geography lessons

Although, there is no significance between age and the effectiveness of GIS as a tool, the percentages on Table 4.17 seem to suggest that older teachers (over 50 years) do not acknowledge the effectiveness of GIS as a teaching tool in teaching geography when compared to the relatively younger teachers who scored 100%, 94% and 94% respectively.

Comment on item 3

Variable iii had a p-value 0.035 which is less than the significance level (0.05). On this variable we conclude that there is association on the teachers' need for GIS training.

Table 4.17: Cross-tabulations of GIS as a teaching tool by age (questionnaire data, n=50)

GIS as a teaching tool		Age				Kruskal-Wallis Test		
		26-29 Years	30-39 Years	40-49 Years	≥50 Years	χ^2	df	p-value
GIS is an effective teaching tool that I can use in geography lessons	Strongly disagree	0	0	0	1			
	Neutral	0	1	1	1	4.490	3	0.213
	Agree	3	7	4	1			
	Strongly agree	9	8	12	2			
	%agree/strongly agree	100%	94%	94%	60%	**No Significant difference in mean ranks**		
	Mean rank	29.25	22.94	27.71	17.20			
Computers with the GIS software, projector are essential to have in teaching GIS in class	Neutral	0	3	2	0			
	Agree	7	10	6	5	5.789	3	0.122
	Strongly agree	5	3	9	0			
	%agree/strongly agree	100%	81%	88%	100%	**No Significant difference in mean ranks**		
	Mean rank	28.88	20.63	29.47	19.50			
Geography teachers need GIS training	Disagree	0	1	0	0			
	Agree	1	7	4	0	8.626	3	0.035
	Strongly agree	11	8	13	5			
	%agree/strongly agree	100%	94%	100%	100%	**Significant difference in mean ranks**		
	Mean rank	29.96	19.34	26.24	32.00			
The use of GIS in Geography courses is required	Disagree	0	0	0	1			
	Neutral	1	5	6	1	3.534	3	0.316
	Agree	4	5	6	1			
	Strongly agree	7	6	5	2			
	%agree/strongly agree	92%	69%	65%	60%	**No Significant difference in mean ranks**		
	Mean rank	31.79	24.72	22.68	22.50			

In summary the results showed that the percentage of participants who believed that computers with GIS software and projectors are essential to have in the teaching of GIS in classes are not significantly different between and across the age groups ($\chi2=5.789$, df=3, p-value=0.122). There are some significant differences among the four age groups on whether they believe that there is need for geography teachers to undergo GIS training ($\chi2=8.626$, df=3, p-value=0.035). This is mainly due to those teachers who are 50 years and older. All age groups unanimously agreed that the use of GIS in teaching Geography topics is required ($\chi2=3.534$, df=3, p-value=0.316) and their view is aligned to the requirement in the latest curriculum document-CAPS.

Geography Teachers' views towards GIS inclusion in the geography curriculum by teaching experience

Teachers' views on GIS inclusion in the geography curriculum were also measured against teachers' teaching experience (TE) and GIS as an effective teaching tool in geography to see whether there was an association. A Likert scale was used to measure items that address GIS as a teaching tool. The t-tests were used to compare two groups and Analysis of variance tests (ANOVA) were used to compare more than two groups in the analyses that follow. The test of association between the variable teaching experience and GIS as effective teaching tool and hypotheses were formulated as follows:

H0: There is no association between the teachers' teaching experiences and GIS as effective teaching tool in geography.

H1: There is an association between teachers' teaching experience and GIS effectiveness as a teaching tool in geography.

On the test of association between the effectiveness of GIS as a teaching tool and teachers' teaching experience, the p-value (0.801) from the Kruskal-Wallis test is greater than the significance level (0.05) hence a failure to reject the null hypothesis and it can be concluded that teaching experience has nothing to do with GIS as an effective teaching tool in geography lessons. There was no significant difference in mean ranks (24.66, 28.73, 24.27 and 25.80). Despite this finding from the questionnaires, the findings from the lesson observations showed that older teachers and teachers who were seasoned in the profession were not comfortable using GIS in their teaching of other themes in Geography.

Results in Table 4.18 showed that the percentages of those who believe in GIS as an effective teaching tool in geography is high across all levels of teaching experience.

Table 4.18: Cross-tabulations of GIS as teaching tool by experience (questionnaire data, n=50)

		Teaching Experience				Kruskal-Wallis Test		
		0-4 years	5-9 Years	10-14 years	15 Years	X^2	df	p-value
TE-GIS is an effective teaching tool that I can use in geography lessons	Strongly disagree	0	0	1	0			
	Neutral	1	0	2	0	1.002	3	0.801
	Agree	4	3	6	2			
	Strongly agree	7	8	13	3			
	%agree/strongly agree	92%	100%	86%	100%	**No Significant difference in mean ranks**		
	Mean rank	24.67	28.73	24.27	25.80			
TE-Computers with the GIS software, projector is essential to have in teaching GIS in class	Neutral	0	0	5	0			
	Agree	9	5	10	4	3.560	3	0.313
	Strongly agree	3	6	7	1			
	%agree/strongly agree	100%	100%	77%	100%	**No Significant difference in mean ranks**		
	Mean rank	25.13	31.77	22.91	24.00			
TE-Geography teachers need GIS training	Disagree	0	0	1	0			
	Agree	1	3	6	2	2.826	3	0.419
	Strongly agree	11	8	15	3			
	%agree/strongly agree	100%	100%	95%	100%	**No Significant difference in mean ranks**		
	Mean rank	29.96	25.32	23.91	22.20			
TE-The use of GIS in Geography courses is required	Disagree	0	0	1	0			
	Neutral	0	2	10	1	9.424	3	0.024
	Agree	4	4	5	3			
	Strongly agree	8	5	6	1			
	%agree/strongly agree	100%	82%	50%	80%	**Significant difference in mean ranks**		
	Mean rank	34.50	28.05	19.84	23.20			

There was an association between teachers' teaching experience and the need to use GIS in the geography lessons, p-value 0.024 was less than significant level 0.05. On this variable, it can be therefore concluded that there is association between years teaching experience and the need to use GIS in geography lessons. Novice teachers with less teaching experience, were younger teachers and they were more at ease using GIS to teach. This finding was also observed in the lessons. Novice and younger teachers were more comfortable with GIS teaching than older and more experienced teachers.

The comparison of geography teachers' Views on whether they see GIS as teaching tool.

Teachers' views on GIS inclusion in the geography curriculum were also measured against the gender of teachers to see whether there was an association. A Likert scale was used to measure items that address GIS as a teaching tool. The t-tests were used to compare two groups and *Analysis of variance tests* (ANOVA) were used to compare more than two groups in the analyses that follow. The test of association between the variable gender and *GIS as effective teaching tool* and hypotheses were formulated as follows:

H0: There is no association between the gender teachers' and GIS effectiveness as teaching tool in geography.

H1: There is an association between teachers' gender and GIS effectiveness as a teaching tool in geography.

On the test of association between the effectiveness of GIS as teaching tool and teachers' gender, the p-value (0.662) from the Wilcoxon's-W test is greater than the significance level (0.05). We fail to reject the null hypothesis and conclude that the effectiveness of GIS as a tool has nothing to do with the teachers' gender. 94 % females and 91 % males agree that GIS is an effective teaching tool that can be used in teaching geography lessons. Also, there was no significant difference in mean ranks (24.84 and 26.03) meaning that most of the teachers agreed with the view that GIS is an effective tool in teaching geography.

Table 4.19: Cross-tabulations of GIS as teaching tool by gender (questionnaire data, n=50)

GIS as a teaching tool		**Gender**		**Wilcoxon-W test**	
		Female	Male	W	p-value
GIS is an effective teaching tool that I can use in geography lessons	Strongly disagree	0	1		
	Neutral	1	2	390.0	0.662
	Agree	6	9		
	Strongly agree	9	22		
	%agree/strongly agree	94%	91%	**No Significant difference in mean ranks**	
	Mean rank	24.38	26.03		
Computers with the GIS software, projector is essential to have in teaching GIS in class	Neutral	0	5		
	Agree	10	18	828.0	0.360
	Strongly agree	6	11		
	%agree/strongly agree	100%	85%	**No Significant difference in mean ranks**	
	Mean rank	27.94	24.35		
Geography teachers need GIS training	Disagree	0	1		
	Agree	3	9	836.5	0.405

	Strongly agree	13	24		
	%agree/strongly agree	100%	97%	**No Significant difference in mean ranks**	
	Mean rank	27.41	24.60		
The use of GIS in Geography courses is required	Disagree	0	1		
	Neutral	4	9	829.0	0.401
	Agree	4	12		
	Strongly agree	8	12		
	%agree/strongly agree	75%	71%	**No Significant difference in mean ranks**	
	Mean rank	27.88	24.38		

GIS promotes learning in the geography class

This section explores geography teachers' views about GIS and learner learning. The section was subdivided into parts that explore the effects of demographic variables on GIS and learner learning. The general view expressed by respondents is that GIS is beneficial to learner learning.

The comparison of geography teachers' Views whether promote GIS learning according to type of school variable

Table 4.20 showed that the percentages of those who believe that GIS supports learner-centred teaching and learning are fairly high for both private (67%) and public schools (70%) and the two percentages are not significantly different (W=1114.5, p-value=0.812). As far as the view that GIS concepts motivates learners to like Geography is concerned, there is a moderate level of agreement among the respondents from the two types of schools.

Table 4.20: Cross-tabulations of GIS and learner learning by type of school.

GIS and learner learning		Type of school		Wilcoxon's W tests	
		Private	Public	W	p-value
GIS supports learner-centred teaching and learning	Neutral	2	13		
	Agree	1	14	1114.5	0.812
	Strongly agree	3	17		
	%agree/strongly agree	67%	70%	**No Significant difference in mean ranks**	
	Mean rank	26.75	25.33		
GIS concepts motivates learners to like Geography	Neutral	2	18		
	Agree	2	13	1112.0	0.751
	Strongly agree	2	13		
	%agree/strongly agree	67%	59%	**No Significant difference in mean ranks**	
	Mean rank	163.00	1112.00		
GIS lessons support critical thinking and problem solving in learners	Neutral	1	4		
	Agree	1	18	1107.0	0.617
	Strongly agree	4	22		
	%agree/strongly agree	83%	91%	**No Significant difference in mean ranks**	
	Mean rank	168.00	1107.00		

There was a slightly higher level of agreement among those from private schools (67%) than among those from public schools (59%). However, the two percentages are not significantly different (W=1112.0, p-value=0.751).

The levels of agreement with regard to whether, there was a high level of agreement among all respondents (83% for private and 91% for public schools) that GIS lessons support critical thinking and problem solving in learners. There is no significant difference between the views of teachers in private schools and public schools on this (W=1107.0, p-value=0.617).

The comparison of geography teachers' Views, GIS learning and the teacher's age

A relationship was also sought between age and various statements. Table 4.21 shows that the percentages of those who believe that GIS supports learner-centred learning was high across all age groups with slightly lower values for the two middle age groups but there are no significant differences (χ^2=2.255, df=3, p-value=0.521).

Table 4.21: Cross-tabulations of GIS and learner learning by age.

GIS and learning		Age				Kruskal-Wallis Test		
		26-29 Years	30-39 Years	40-49 Years	≥50 Years	χ^2	df	p-value
GIS supports learner-centred teaching and learning	Neutral	2	6	6	1			
	Agree	8	3	4	0	2.255	3	0.521
	Strongly agree	2	7	7	4			
	%agree/strongly agree	83%	63%	65%	80%	**No Significant difference in mean ranks**		
	Mean rank	23.42	25.03	24.91	34.00			
GIS concepts motivates learners to like Geography	Neutral	5	6	5	4			
	Agree	2	5	8	0	2.167	3	0.539
	Strongly agree	5	5	4	1			
	%agree/strongly agree	58%	63%	71%	20%	**No Significant difference in mean ranks**		
	Mean rank	26.96	26.13	26.38	17.00			
GIS lessons support critical thinking and problem solving in learners	Neutral	3	2	0	0			
	Agree	5	4	7	3	3.738	3	0.291
	Strongly agree	4	10	10	2			
	%agree/strongly agree	75%	88%	100%	100%	**No Significant difference in mean ranks**		
	Mean rank	19.50	27.56	28.24	24.00			

As far as the view that GIS motivates learners to like Geography is concerned, there is a moderate level of agreement among the respondents from most age groups with those over the age of 50 years having lower levels of approval, but the differences are not statistically significant (χ^2=2.167, df=3, p-value=0.539). This view maybe because the teachers were old, and they were not au fait with modern technology such as GIS as compared to other participants in other age groups who were relatively young and tech- savvy having grown up in a world which relies on advancements in technology for daily living.

There were high levels of approval among all age groups as far as the view that GIS lessons support critical thinking and problem solving in learners is concerned with all percentages being at least 75%. There are no significant differences across the age groups (χ^2=3.738, df=3, p-value=0.291).

The comparison of geography teachers' Views whether promote GIS learning according to gender variable

Table 4.22 shows that the percentages of those teachers who believe that GIS supports learner-centred teaching. The results are not significantly different (W=814.5, p-value=0.245).

Table 4.22: Cross-tabulations of GIS and learner learning by gender.

GIS as and learner learning		Gender		Wilcoxon's_W tests	
		Female	Male	W	p-value
GIS supports learner-centred teaching and learning	Neutral	2	13		
	Agree	7	8	814.5	0.245
	Strongly agree	7	13		
	%agree/strongly agree	88%	62%	**No Significant difference in mean ranks**	
	Mean rank	28.78	23.96		
GIS concepts motivates learners to like Geography	Neutral	5	15		
	Agree	5	10	824.5	0.347
	Strongly agree	6	9		
	%agree/strongly agree	69%	56%	**No Significant difference in mean ranks**	
	Mean rank	28.16	24.25		
GIS lessons support critical thinking and problem solving in learners	Neutral	2	3		
	Agree	6	13	396.0	0.781
	Strongly agree	8	18		
	%agree/strongly agree	88%	91%	**No Significant difference in mean ranks**	
	Mean rank	24.75	25.85		

As far as the view that GIS concepts motivate learners to like Geography is concerned (Table 4.22: Questionnaire), there was a moderate level of agreement among the teachers from both females (69%) and males (56%) and the groups are not statistically significant (W=824.5, p-value=0.347).

There are high levels of approval in both females (88%) and males (91%) on the view that GIS lessons support critical thinking and problem solving in learners and the two groups were not significantly different (W=396.0, p-value=0.781). This finding from the interviews is also in agreement. Both male and female teachers agreed that GIS supports learner centredness, it motivates learners to like geography and it supports critical thinking and promotes problem solving in learners more especially when they do GIS related assignments. The majority (80%, n=8) of the teachers interviewed in this research agreed with the views highlighted on Table 4.22. However, relatively old teachers (the over 50 years of age), were of the contrary view.

The comparison of geography teachers' Views towards GIS according to race variable

The relationship was also sorted to find out whether GIS usage was influenced by the race of the teachers who participated in this study. The results in Table 4.23 show that the percentages of those who believe that GIS supports learner-centred teaching and learning was high across all races although slightly higher among the Whites (86%) than the other races. However, there are no significant differences across race (χ^2=3.044, df=2, p-value=0.218). The results across all the three tools (questionnaire, interviews, and lesson observations) used in this research point to one conclusion that indeed GIS supports learner-centred teaching and learning. Most of the participants were in agreement.

Table 4.23: Cross-tabulations of GIS and learner learning by race.

GIS as and learner learning		Race			Kruskal-Wallis Test		
		Black African	White	Coloured	χ^2	df	p-value
GIS supports learner-centred teaching and learning	Neutral	10	1	4			
	Agree	6	1	8	3.044	2	0.218
	Strongly agree	12	5	3			
	%agree/strongly agree	64%	86%	73%	**No Significant difference in mean ranks**		
	Mean rank	25.14	33.36	22.50			
GIS concepts motivates learners to like Geography	Neutral	13	0	7			
	Agree	9	2	4	7.609	2	0.022
	Strongly agree	6	5	4			
	%agree/strongly agree	54%	100%	53%	**No Significant difference in mean ranks**		
	Mean rank	23.09	38.71	23.83			
GIS lessons support critical thinking and problem solving in learners	Neutral	2	1	2			
	Agree	12	2	5	0.020	2	0.990
	Strongly agree	14	4	8			
	%agree/strongly agree	93%	86%	87%	**No Significant difference in mean ranks**		
	Mean rank	25.39	26.14	25.40			

As far as the view that GIS motivates learners to like Geography was concerned, there was significant differences among different races. White teacher participants (100%) had positive views about the effects of GIS on learners. Black African teachers (54%) and Coloured teachers (53%) had similar levels of agreement and the racial groups were statistically significantly different (χ^2=7.609, df=2, p-value=0.022). This statistically significant difference can be due to GIS knowledge exposure and what GIS can offer in really life situations. In most cases White teachers are teaching in private and former model C schools which are historically privileged compared to schools where most black African teachers and coloured teachers are teaching which have historical disadvantages which continue into the present.

There are high levels of approval amongst the three racial groups on the view that GIS lessons support critical thinking and problem solving in learners and there are no statistically significant differences (χ^2=0.020, df=2, p-value=0.990). Also, findings from the interviews and lesson observation showed similar trend. Overall, all the races held the view that GIS support learner-centred learning expect few teachers who were not sure about this view. Mr Ngubane and Mr van Wyk, were not quite sure about whether GIS supports learner-centredness or not. Mr Ngubane explained that:

I am not quite sure whether GIS can support learner-centred learning because I have never fully implemented it. The challenge I have at this school is the lack of GIS lab, GIS software and data. Also, personally, I do not know much about GIS. I only teach my learners what is in the textbook.

Also, the lesson observation I made with Mr Ngubane confirmed what Mr Ngubane said. Mr Ngubane who was observed teaching: Spatial and Spectral resolution in grade 10. He did not explain anything to the learners related to the key concepts in the topic. He simply wrote the notes on the chalkboard and asked one learner to read what was in the textbook. After reading and writing the notes on the chalkboard he asked the learners to do activity in the textbook. There was negligible interaction between the teacher and his learners which clearly compromised his teaching and deep learning.

GIS and learner learning by Teaching Experience

The results in Table 4.24 show that the percentages of those who believe that GIS supports learner-centred teaching are moderate in most categories of experience but very high in those with the least experience (92% for 0-4 years). However, the differences are not statistically significant (χ^2=6.122, df=3, p-value=0.106).

Table 4.24: Cross-tabulations of GIS and learner learning by experience.

GIS as and learner learning		Teaching Experience				Kruskal-Wallis Test		
		0-4 years	5-9 Years	10-14 years	15 Years	χ^2	df	p-value
ST-GIS supports learner-centred teaching and learning	Neutral	1	4	8	2	6.122	3	0.106
	Agree	3	5	7	0			
	Strongly agree	8	2	7	3			
	%agree/strongly agree	92%	64%	64%	60%	**No Significant difference in mean ranks**		
	Mean rank	33.42	20.73	23.11	27.50			
ST-GIS concepts motivates learners to like Geography	Neutral	4	5	9	2	1.042	3	0.791
	Agree	3	4	6	2			
	Strongly agree	5	2	7	1			
	%agree/strongly agree	67%	55%	59%	60%	**No Significant difference in mean ranks**		
	Mean rank	28.42	22.77	25.61	24.00			
ST-GIS lessons support critical thinking and problem solving in learners	Neutral	2	0	3	0	1.781	3	0.619
	Agree	4	4	9	2			
	Strongly agree	6	7	10	3			
	%agree/strongly agree	83%	100%	86%	100%	**No Significant difference in mean ranks**		
	Mean rank	24.25	29.32	23.59	28.50			

Levels of agreement on whether GIS motivates learners to like Geography are moderate for all levels of experience (all around 60%) which is not significantly different statistically (χ^2=1.042, df=3, p-value=0.791).

There are high levels of approval across all levels of experience the view that GIS lessons support critical thinking and problem solving in learners and there are no statistically significant differences (χ^2=1.781, df=3, p-value=0.619).

These views from the teachers who participated in this research through a questionnaire were also echoed by the teachers who were interviewed (pre and post lesson observations) and observed when they were teaching GIS topics. Table 4.25 gives a summary of the findings.

Table 4.25: Summary of emerging themes on teachers' views (perceptions) about GIS in the geography curriculum (data from 10 participants)

Themes	Response frequency
GIS is difficult to teach	8
GIS is a practical concept that needs hands-on experience	7
Helps learners think critically	6
Promotes teamwork	7
GIS carrying small weighting	6
Helps learners solve real-life environmental problems	8
Promotes learner-centred teaching and learning	7
GIS helps the learners to like geography	5

The results showed that geography teachers had different views about GIS in geography. As indicated in Table 4.25, seven themes emerged from the responses of the 10 geography teachers who were interviewed. The results showed seven themes on Table 4.25.

GIS is difficult to teach.

For example, Mr Van Wyk, at School 1, stated that,

Yeah, GIS is a difficult subject, we do not have the computers and the datasets, and I don't have much knowledge in the subject.

Mr Robson at School 5 said,

I enjoy teaching GIS, umm at times it's difficult because of limited resources.

Ms Fatima at School 3 (rural school) stated that:

It was quite difficult at first because the computer lab that is there, we share it with the computer application technology subject, so the planning of the timetable was quite difficult. A large number of learners are doing geography, so you find out that the issue of not having enough resources like computers is a bit challenging.

The other view which featuresfrequently is that GIS carries a small weighting in the matric examination

GIS in the blueprint curriculum

The following interviews extracts revealed this theme. Ms Mable explained that:

The issues of time is one major issue because when you check on the time table, GIS is allocated, its according to the CAPS document, its allocated just the same time as other topics, *but you know with practical subject you need more time for you to finish so if you need to do GIS thoroughly the way you are supposed to teach it you would find out that you won't finish the syllabus because the time allocated is very little. Also, GIS questions in Grade 12 only carries a small percentage.*

Mr Robson also stated that**:**

Most of the learners don't take the topics of GIS seriously hence they find GIS as hard topics to understand. GIS section does not carry a lot of marks in Grade 12 examination. I only concentrate on teaching the GIS topics for the learners to able to answer the section. The syllabus is long and usually I put more emphasis on the sections that carries a lot of marks in the examination (Grade 10, 11 &12).

Mr Ngubane explained that:

I have been teaching geography for a long time, the syllabus is long. The section of GIS contributed very little marks in matric examination. I only teach this section to make learners able to answer that section. There nothing I can do. GIS section is difficult to teach. I did not learn GIS when I was training to become a teacher.

The above extras revealed two important views highlighted by the teachers. The teachers are of the view that the time allocated to GIS section in the curriculum is insufficient. The teachers stated that GIS is a practical concept and hence needs to be treated as such and allocated adequate time so that the learners can gainfully learn. The other view which came strongly in this research was that the GIS assessment in the Geography FET Curriculum carries a small weighting. As a result, most teachers do not prioritise much time when they teach geography. Most of the teachers resort to making learners memorising the answers before they write their examination.

GIS is practical and needs hands-on experience

The results also showed that seven (70%) geography teachers stated that GIS was practical and needed hands-on experience. These teachers were of the view that GIS should be taught in a computer laboratory with GIS software.

When Ms Fatima, located at School 3, was asked about the approaches she used to teach GIS, she explained that:

Yes, there are quite a number of teaching methods, but with GIS, there are the most conducive. I mean the most appropriate methods to use, considering that GIS is more practical, it is more of a practical concept so the learners need to be involved with a hands-on *approach, they need to be involved in active learning and find out like if you talk GIS in concept without practical it will be very difficult for learners to understand.*

Well, I would say that without resources, like using the hands-on approach it becomes very difficult because it's difficult to explain to someone who has never done GIS, what resolution is, you need to show them the resolution, the spectral resolution, what raster data is, they must see and all that, but if there is enough technology, computers and the software, it becomes quite interesting and very easy to teach.

Ms Fatima emphasised that GIS needs hands-on experience, and that the learners need to be involved in learning GIS practically. She suggested that GIS would be easier to understand through practice, than to learn it theoretically.

Develops critical thought and promotes teamwork

Nevertheless, six geography teachers from the interviews believed that GIS encourages learners to think critically and enables them to solve environmental problems. Seven participants from the interviews were of the view that GIS promotes teamwork among learners. Learners can share ideas and duties when they are given a GIS project to complete. For example, when Mr Douglas was asked how he felt about the introduction of GIS in the geography curriculum, he stated that,

I think it was the best idea considering that everything in life is GIS (technology rules now), so I think it is the best idea and it also helps the learners, you know, to have inquisitive minds and it promotes critical thinking.

Eight participants from the interviews indicated that GIS helps learners to solve real-life problems, and seven stated that GIS teaching promotes learner-centred teaching and learning in the class.

For example, Mr Robson at secondary School 5 stated the following:

It is the best idea because it opens the learners' minds and assists them in developing inquisitive minds.

GIS promotes learners' love of geography

Finally, five participants from the interviews were of the view that GIS promotes learners' desire to learn geography especially about the environment surrounding them.

Ms Fatima at School 3 stated that:

Definitely yes, it is definitely going to help the learners and after teaching you would see that they were not aware that everything that involves the earth and life, is GIS. The moment they *start knowing that it makes them even more interested in learning about GIS and developing some interest in geography as a subject and the environment surrounding them.*

Overall, the data from both the questionnaires, interviews and the lesson observations showed that most of the teachers have a fair view and knowledge of what GIS is all about and what it can do; these views were shared by the majority of the participants. In addition, a cross-tabulation of the participants' views by gender, race and age showed almost the same results. The variables gender, race and age did not have significant control over the views expressed by the participants towards GIS. The few teachers who showed less favourable views in relation to GIS indicated that GIS is difficult, that some schools are under-resourced, and that it takes a lot of time to teach and learn GIS. For instance, Ms Mable from the rural school I visited explained that:

GIS topics are difficult to teach because I do not have enough resources such as textbooks and maps. Most of the times learners share textbooks. Also, personally, I did not get much training in teaching GIS which becomes a big challenge to me. During GIS lessons I only use the textbook and make the learners read and I write the notes on the chalkboard for the learners to copy. There is nothing I can do beyond that because we are under resourced at this school.

Ms Mable raised very fundamental concerns in her response. She raised the issue of a lack of textbooks which is a huge problem affecting most of the schools more especially rural schools in South Africa. Most schools in rural areas are under resourced and classes are overcrowded (Du Plessis & Mestry, 2019; Wilmot & Dube, 2015). Also, in her response, Ms Mable stated that she did not get much training in GIS. Her response concurs very much with the responses from the questionnaire analysis. Many teachers indicated that they did not get adequate training in GIS. The geography teachers attended few GIS workshops which were not enough in terms of time and in terms of hands-on practice on some of the GIS concepts. The talk on GIS just lasted for about 30 minutes. Ms Mable said that the presenter gave a power point presentation on how some of the GIS questions were supposed to be answered. What I noticed during this workshop Was that most of these workshops are integrated with matric results analysis, of which they are insufficient for teachers to master the concepts taught is such workshops. In 2016, I, as a researcher, was invited to one of these workshops at Elizabeth Conradie School in Kimberley. The deliberation on GIS was very brief and unproductive. The workshop was mainly in a lecture method and it was not interactive allowing engagement with the teachers. The presenter gave a power presentation on how the grade 12 learners were supposed to answer the GIS questions in the 2015 geography examination paper. So, it was merely assessment driven for the high stakes examination and not to build GIS knowledge or skills amongst the teachers.

Mr Robson explained the following regarding his GIS knowledge:

GIS teaching makes me shiver and I lost confidence. I always struggle to explain the concepts of GIS when I teach my class. I don't have proper gadgets and materials to teach this section. I tried to download QGIS on my personal laptop, but internet and how to execute some of the functions and demonstrate some of the concepts is still a big challenge to me.

Mr Robson's response revealed many insights regarding GIS teaching. Mr Robson mentioned one of the major problems of fear and a lack of confidence which teachers struggled with when it comes to the application of the technology in the class. Many teachers lose confidence due to a number of reasons. Some the reasons, evident in the literature, which makes people lose confidence is a lack of technological knowledge (TK). If a person does not have technological knowledge, he/she will fumble for the necessary knowledge and lose confidence in explaining the content to the learners (Filgona, Sakiyo, Gwany & Okoronka, 2020). Some people may end up showing negative attitudes towards the technology and to the learners they teach (Özden, 2008).

After listening to Mr Robson's response during the interview, I probed him further in trying to understand what he meant by a lack of gadgets and material.

Mr Robson stated the following:

In this school I don't have topographical maps, computers and GIS software. If I had all these physical materials it will be far much better because I can try to show the learners some of the things on the map and on the computer. I tried to get some more information on GIS from the department of education but still I couldn't get much help. This makes it very challenging to teach GIS in this school.

I probed Mr Robson further in order to get more information about what kind of help he wanted, and he got.

Mr Robson further replied by explaining that:

I went to the Department of Education in the Frances Baard District and approached the subject adviser to help me with some GIS resources I could use in my class. Unfortunately, the subject advisor couldn't adequately help me with GIS material I requested. I then approached the Sol Plaatje Municipality in the GIS department and I was able to get some of the GIS data (in soft copies). Now my problem is how to display and use that data for my class since we don't have computer lab in our school. I can use my personal laptop, but still is difficult *because my classes are large, and it will be difficult for every learner to see unless I had a projector.*

Mr Robson also aired the same sentiments as many teachers did lack the needed resources to teach GIS. This is a major challenge in numerous schools in more especially in rural schools and in township schools. Mr Robson mentioned that if he had all the equipment needed to teach GIS, he would have a different view about GIS. He also mentioned that he tried to get help from the Department of Education but to no avail. He finally acquired some of the resources from Sol Plaatje Municipality in the GIS department, but his challenge is the lack of a computer lab. He stated that if the school can provide him with a projector, at least he can use his personal laptop to demonstrate some of the GIS data, like raster and vector data, attribute tables on population which he sourced from the municipality. Mr Robson's responses showed that the Department of Education is under resourced from a personnel point of view.

Mr Rua explained that:

Teaching of GIS in most of my classes is a big challenge. I teach geography from grade 10 to 12 and my classes are large. I don't have enough textbooks and material to use when teaching GIS. It is very difficult to stand in front of the class when the learners do not have textbooks. Most of the times I read the textbook and write the notes on the chalk board. I don't have any option. I always fail to get enough time to research more especially on GIS for my lesson, so I simply come to class with the little I have. I have only attended one workshop for GIS, and this makes it difficult to remember everything we were taught there. Some of the things which were mentioned needs practical, practice with hands and a computer.

Mr Rua raised a number of issues in his responses which are fundamental and prevailing in other schools (Mzuza & van der Westhuizen, 2019). The issue of large classes is a challenge more especially in rural and township schools. Large classes tend to hamper learning in many ways. The teachers cannot monitor and ensure that the learners understand the content being taught. For instance, I observed that Mr Rua's class was characterised by noise and indiscipline and some of these indiscipline tendencies emanated from the fact that his class was large. The teacher would spend much of the time in trying to make the learners listen to the teacher. The issues he raised are the lived experiences for him. In one of the lessons which I observed, the teacher spent almost half of the teaching time in trying to settle the learners who were noisy. Ms Abigail whom I observed teaching the topic: Data Manipulation and application of GIS techniques in Grade 12 was struggled to control the class. The majority of the learners came to class late and some of the learners had no chairs to sit on and they spent the whole lesson standing.

It is clear from these responses that the majority of the participants were frustrated due to a lack of resources and time to plan and implement GIS teaching. Furthermore, the teachers reported that there was a lack of training and curriculum materials needed to teach GIS. The teachers also reported that some classes of geography were overcrowded which made their jobs very difficult more especially in township and rural schools which were under resourced. Most of the schools in rural areas do not have enough geography textbooks. In one the rural school, I observed Ms Letimia teaching the topic: Data Capture in grade 11. There was shortage of Platinum textbooks in her class. Learners had to share the few textbooks which were available. Also, the furniture especially the chairs, were not enough for all the learners during that geography lesson. The shortage of chairs actually delayed the commencement of the lesson as the learners were instructed to go and look for the chairs in the other classrooms. I found this situation to be very disruptive and impacted on the outcomes for the lesson not being reached in the allocated class time.

4.3.3 RESEARCH OBJECTIVE 3: TO EXPLORE THE PEDAGOGICAL APPROACHES USED TO TEACH GIS

This objective was answered by responses to Section D of the questionnaire, the interviews and the lesson observation made in this research. The first part of the questionnaire was intended to find out which GIS topics in the geography curriculum were the teachers teaching. The majority of the participants stated that the GIS topics they teach depended on the grades they teach, and it is solely dependent on the geography curriculum. In Grade 10, the participants teach the history of GIS, how it developed, reasons for the development of GIS, how remote sensing works, types of remote sensing and components of GIS and data capturing. In Grade 11 teachers teach spatial reference data, geographic coordinates, spatial and spectral resolution, types of data, data formats, the application of GIS, and data capture. In Grade 12 they teach aspects of GIS such as types of satellites, remote sensing and resolution, spatial and attribute data, data standardisation, data sharing and data security, data manipulation and application of GIS techniques, and paper GIS. The analysis of the participants' responses to the questionnaire survey reflects what is contained in the geography textbook and the CAPS document, are the only sections in GIS that are being taught. The findings showed that the participants knew what was expected of them and what they were supposed to teach in the FET phase, but it also indicates that they did not go beyond the syllabus.

Pedagogical approaches used by the teachers from the questionnaire survey (n=50)

The researcher wanted to identify the most commonly used pedagogical approaches used by the teachers when they teach GIS. These pedagogical approaches were broadly divided into teacher-centred and learner-centred approaches. When teaching geography and GIS in particular, there are teaching methods and techniques that are used within each pedagogical approach. Teachers employ almost the same pedagogical approach they use when they teach other topics in geography. The results are displayed in Figure 4.1.

Teacher-centred pedagogical approaches

Teacher-centred pedagogical approaches were the main pedagogical approaches used by most of the teachers in this research. The teaching methods employed by most of the participants were, explanation had 36%, questioning (32%) and lecturing (20%) (Figure 4.1).

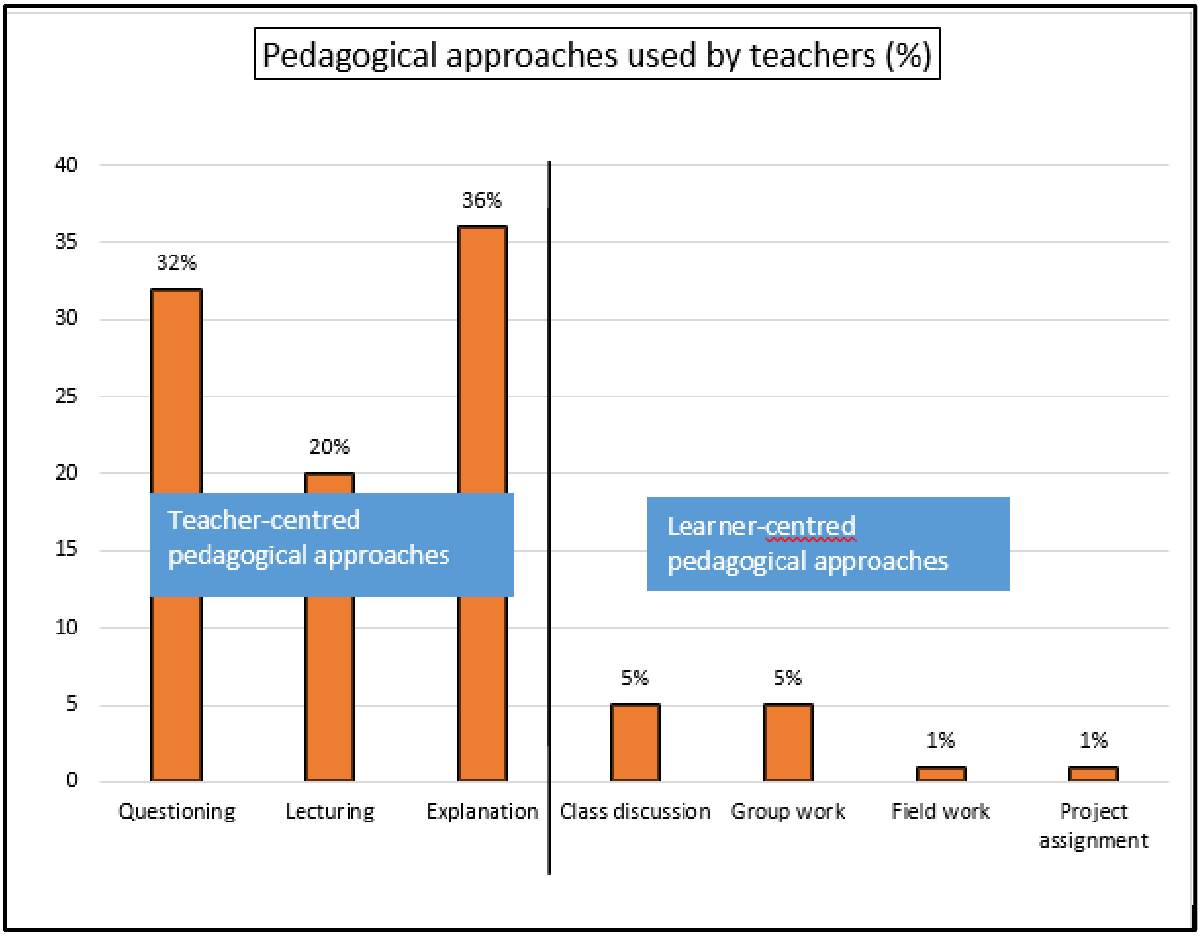


Figure 4.1: Pedagogical approaches used by participants to teach GIS (data from the questionnaire)

Learner-centred pedagogical approaches

On the contrary, very few teachers were using learner-centred pedagogical approaches (Figure 4.1). The main teaching methods under learner-centred pedagogy were Class-discussion (5%) and Group work (5%), followed by Field work (1%) and Project assignment (1%). The next section discusses these pedagogical approaches in more detail.

Similarly, the findings from the interviews and lesson observations showed almost the same pedagogical approaches used by the teachers. The majority (80%) (n=8) of the teachers who were interviewed stated that they used lecturing, explaining and questioning as teaching methods and strategies and that they do not limit themselves to one but used a mixture. In most instances, the teachers used two or more methods in different stages of the lesson development. The majority of the teachers who took part in this study taught GIS using teacher-centred pedagogical approaches. The commonly used pedagogical approaches and teaching methods are summarised Table 4.6 below and will be discussed in depth in the following section.

Table 4.26: A summary of teaching methods participants used (data from the interviews (n=10)

School No.	Teacher	Summary of teaching methods
1	Mr Van Wyk	Explaining, questioning, groupwork, class discussion, demonstration
2	Mr Tau	Explanation, questioning and lecturing, practical (multiple)
3	Ms Fatima	Class discussion, practical demonstration, groupwork (multiple)
4	Ms Mable	Explaining, questioning and lecturing
5	Mr Robson	Group work, collaborative problem solving
6	Mr Douglas	Explaining, groupwork,
7	Ms Letimia	Explaining, questioning
8	Mr Rua	Explaining, lecturing, questioning method
9	Mr Ngubane	Explaining, lecturing method
10	Ms Abigail	Lecturing and explaining

Explanation as a teaching method

Data collected from all the three research tools (questionnaire, interviews and lesson observations) showed that the majority of the teachers used explanations as the main method. This method is linked to a teacher centred pedagogical approach and it was mainly used at middle of the lesson development stage when the teachers were explaining the concepts of GIS to the learners. The teachers said that they used this method because the topics they were teaching in GIS were new to the learners and were not familiar to the learners and therefore greater explanations were required.

Mr Tau at School 2 (lesson observation 2), who was observed teaching the topic, Components of GIS to Grade 10, used explanation and questioning methods. Mr Tau's class had 59 learners and on the day of the lesson observation, seven learners were absent. Mr Tau started his lesson by recapping the previous lesson's key points on the meaning of GIS, its history and functions and why it is important.

Mr Tau then asked the question: What is GIS? He identified a learner at the back of the class, who answered that GIS refers to geographical information systems. Mr Tau probed the class further, by asking: What does GIS do? No learner was able to respond to the question. Mr Tau then responded by providing the answer to the question himself.

Geographic information systems is an abbreviation for geographic information systems. It's a computer program that can record, store, manipulate, analyze, manage, and display a wide range of spatial and geographic data.

After recapping the previous lesson's key concepts, Mr Tau introduced the new topic, the components of GIS, by displaying some pictures of GIS components on the white board and he asked the learners to name them. Figure 4.2 showed the images, and it was followed by the explanations of the functions of the GIS components that Mr Tau gave to his class.

Figure 4.2: The components of GIS

Hardware (computers)

A computer on which GIS runs is referred to as hardware. GIS software is executed on a computer's hardware. These can also use a smart phone as a hardware. For example, we can take a picture using the cell phone and download on the computer. This is simple, isn't it? Also, we can use a GPS instrument.

Mr Tau showed a GPS instrument and a laptop he had brought to class as examples of hardware used for GIS.

Software

GIS software contains tools and functions for storing, analyzing, and displaying geographic information. The major software components include tools for importing and altering geographic data, a database management system (DBMS), and tools for geographic query, analysis, and visualization.

Data

Information that can be collected and saved in GIS software is referred to as data. A GIS can combine spatial data with other data sources and use a database management system (DBMS) to edit data and create maps, graphs, and charts, among other things.

People

People refers to people like you, who can use GIS technology to put the data into the computer, manage the system and make maps using GIS.

Ms Mable at School 4 (lesson observation 4) also used the explanation and questioning pedagogy. Ms Mable was observed teaching the topic Querying and Statistics Analysis to Grade 12. Ms Mable's class had 55 learners of whom 5 learners were absent on the day of the lesson observation. Ms Mable commenced the lesson by checking the learners' homework and giving feedback to the learners. During the homework feedback, the teacher involved the learners, by asking them to give the answers to the homework questions. The following quotations were some of the questions and responses given by Ms Mable.

She asked, what was buffering? A few learners put up their hands. Before Ms Mable could select a learner to respond, she asked the class, why the learners were not putting up their hands. Didn't you do the homework? Then, the teacher selected a learner to give the answer. She gave a full answer:

A buffer is reclassification based on distance. It entails measuring distances in all directions away from an object. Buffering can be applied to any of the three types of vector data: point, line, or area. The buffer that results is a polygon file.

The teacher asked the second question: What is data integration? Again, a few learners put up their hands. The teacher selected one learner who tried to answer the question but gave the wrong answer. The teacher said, thank you for trying, did not probe the learner and went on to give a full explanation of what data integration is:

The process of merging data from diverse sources and giving consumers with a single view of that data is known as data integration. It is like combining cows, donkeys and goats in one kraal. For example, we can combine population data and area data to calculate population density.

Then, the teacher introduced the topic of the lesson. She wrote the topic on the chalkboard and asked one of the learners to read from the textbook. The teacher then moved around the classroom showing the learners the statistics table in the textbook. The teacher asked the class, what is querying? No one answered the question. The teacher then wrote the definition of querying on the chalkboard without explaining the meaning of the concept. She just read aloud what she had written on the chalkboard. The teacher used passive strategies throughout the lesson. The was mainly due to lack of teaching materials and not knowledgeable of other teaching approaches which can involve learners.

A query layer is a layer that a SQL query defines. Query layers make it simple to integrate spatial and non-spatial data from a database management system into ArcMap GIS projects.

Ms Mable and Mr Tau used the explanation and questioning methods differently. Mr Tau (lesson observation 2) involved a number of learners in his explanation while he taught the lesson. The learners were involved in the lesson when they were asked to name the GIS components. Mr Tau's explanation was structured and ordered, and he explained components of GIS, one after the other, in a logical order, starting with hardware followed by software and then data. The explanation was sequential and well connected (Criticos et al., 2002). The explanation he gave in the lesson provided ideas on the functions of the components of GIS. The teacher used an interpretive explanation, which served the purpose of explaining what something is (Criticos et al., 2002), and was aimed at clarifying concepts. In addition, the teacher mixed explanation as a pedagogy with other appropriate techniques. He accompanied his explanation with questions, demonstrations and illustrations. He complemented verbal explanations with visual supports, such as charts and pictures of GIS components, while presenting the lesson. Instead of using only the sense of hearing while explaining the functions of the components, learners could also use their sense of sight to see the pictures of the GIS components on the whiteboard. He strengthened the sensory perception (sight and hearing) further by instructing the learners to touch and feel the GPS instrument that he had brought to the lesson.

In Ms Mable's class (lesson observation 4), the learners were partly involved in the construction of knowledge. The explanation of the concepts was neither logical nor well structured. For instance, the abbreviation SQL, used when the teacher gave the definition of querying data, was not explained. Ms Mable's explanation techniques failed to help the learners understand the concepts learnt in this class. The explanations given were not repeated in different ways to ensure that learners understood the concepts. The learners were not fully engaged in the lesson – engaging learners helps both the learners and the teacher and helps the teacher, in particular, to check whether the learners understood the concept, or not. If learners fail to understand, the teacher can identify the misconception and find a better way of explaining the concept (Criticos et al., 2002). The explanations were not clear, because teacher Mable merely read the definitions of the terms buffering, querying and data integration form the textbook. The teacher was basically textbook dependent, and it looked like Ms Mable didn't quite understood the concepts she was teaching herself. The reasons for this lack of knowledge were that Ms Mable said she did not get any training in GIS. When I asked her to evaluate her lesson during the post-lesson observation interview session, she stated that:

The topics of GIS in grade 12 are difficult to teach. I don't have any knowledge myself. It is my first time to teach this section in grade 12. The training we received from the Department of Education did not helped me at all because I did not grasp anything at all. As you can see, I don't have any laptop or computer lab I can try to show some of the images of GIS.

When I further probed her asking what needs to be done, she suggested the following*:*

I wish if the Department of Education can give us more training, send an expert to come and educate us on the GIS topic. This GIS need a computer lab or a laptop with some GIS software and data sets such as maps and notes. I am just teaching the learners to memorise the answers for this section. I wish I can do it better.

During the lesson observation there was very little participation from the learners. The closest she came to engaging the learners' other senses, and not merely their sense of hearing, was when she walked around the class showing the table of statistics in the textbook. The teacher could have done more, by actually drawing the querying table on the chalkboard and explaining it to the learners, so that they could see the attribute table, instead of only showing them in the textbook. Explanations should help learners make connections between steps of the explanation (Criticos et al., 2002) and yet, in Ms Mable's case, no connections were made, as the explanation was not supported by any visual aid during the lesson.

The learners who tried to ask questions during Ms Mable's lesson were not accommodated. The teacher failed to give satisfying responses to the questions the learners asked. It seems that Ms Mable's knowledge of the concepts was very limited. The learning environment in Ms Mable's class was inviting for interaction. Desks and chairs were neatly arranged, and this gave the teacher room to walk around and monitor the learners' progress, but it was not designed in any way to promote learning about GIS. The teacher did not utilise all the advantages of the classroom environment offered, to improve her pedagogical approaches.

Questioning as a method

Questioning as a method is a teacher centred pedagogical approach and it was the second-most-widely used by participants in this research. The data from the interviews and lesson observations showed that the majority of teachers used the questioning method. Also, the data from the questionnaire survey showed that the questioning method was used by the majority of the teachers 32% of teachers.

Questioning within the lessons and the use of questions

Questioning was mainly used at the beginning of the lesson and the conclusion of the lesson. Most teachers used questioning when they were recapping the previous lesson's main concepts to check understanding from the learners. Questioning is used in a lesson for a number of reasons. Research in countries other than South Africa such as Kenya, Ghana, Finland, USA found that teachers use the questioning method to manage the class, rather than to help learners understand the concepts (Criticos et al., 2002). This is confirmed by the way Ms Mable used the questioning technique largely to manage her classroom. During the lesson she asked the learners:

Why are you not putting up your hand? Didn't you do the homework?

This question is an example of a classroom management type of questioning that does not check the learners' understanding, nor does it motivate the leaners to understand the topic which she was teaching during the lesson. Ms Mable (lesson observation 4) seldom used the questioning approach to foster learning and understanding of GIS, despite the questioning being effective when it is used at the right time. Teachers should make a decision when to use questions. For example, Mr Van Wyk at School 1 (lesson observation 1), who was observed teaching the topic of Remote Sensing and Resolution to Grade 12, used questioning, explanation, demonstration as teaching methods. Mr Van Wyk's class had 36 learners and on the day of the lesson observation, one learner was absent. The teacher commenced the lesson by checking homework and used the pedagogy of questioning to check the learners' understanding of the concepts he had taught previously. The following extract is an example of the questions he asked during the lesson:

What is remote sensing? Remote sensing takes place in two main ways, what are those ways?

The teacher paused after asking each question, and repeated the question several times, giving the learners time to respond to his question.

Questioning and associated methods

Questioning was used to probe and to ensure deep learning by learners. In addition, the sequencing of the questions helped to probe the understanding of the learners. The teacher probed further after a learner gave an answer, to check whether the learner was sure of the answer he/she was giving. For instance, one leaner said that one way in which remote sensing takes place is by passive sensing. Mr Van Wyk probed further by asking the learner, “Can you explain what passive sensing is and what is the different between passive sensing and active sensing?” The teacher asked a follow up question to further probe which promoted a critical thinking in the learners. From the lesson observation I made in this lesson, this probing and rephrasing the question in a simply way helped the learners to engage in critical thinking as they start participating after the teacher had rephrased the question,

Questioning was also successfully used by Mr Wyk together with other methods, namely explanation and demonstration, for a successful GIS lesson. Mr Van Wyk introduced the new topic after giving feedback on the homework, by asking questions that connected the previous section with the new topic. He explained that remote sensing is information we get from space, the air, and spaceships (satellites). To aid his explanation, he drew the example of spaceship taking pictures and sending the information to the computer on the ground (earth). Mr Van Wyk used the photo in Figure 4.3 to aid his explanation.

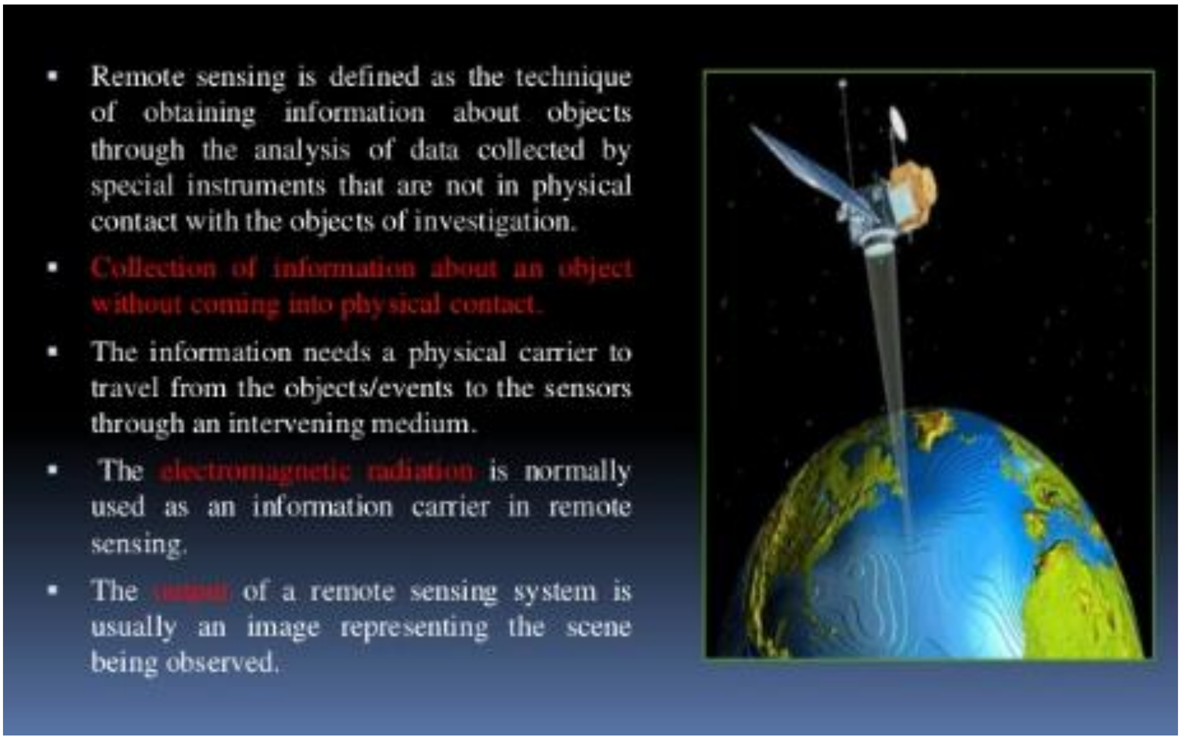


Figure 4.3: **How remote sensing works**

After explaining the concept of remote sensing, the teacher introduced the concept of resolution to the class. He asked learners to take out their cell phones, to take a picture and then demonstrate resolution by zooming in and out. He then asked the learners to describe, in pairs, what happens to the picture. From the beginning of the lesson, to the end of the lesson, Mr van Wyk used a learner-centred pedagogical approach in his teaching. He involved the learners in the construction of knowledge by using the questioning, explanation, and demonstration. In addition, the teacher was innovative in his approach and he exhibited a deep understanding of the content knowledge.

Lecture as a method

Lecturing as a method, another teacher centred pedagogical approach, was successfully used by Mr Ngubane when he was teaching the topic: Spatial and spectral resolution in grade 11. This is one of the oldest teaching methods. It is a method of teaching and learning in which the teacher uses verbal communications to pique his pupils' attention, influence and stimulate them, and engage them in learning. (Benjamin & Wakhungu, 2014). Mr Ngubane employed a formal type of lecture method whereby he was the only one who was talking while the learners were taking notes during the lesson. Formal lecture is more suited in Geography and GIS topics since it gives the teacher with feedback from the learners. . Mr Ngubane explain the concepts on Spatial and spectral resolution because the content he was teaching was more factual information and his class was large. Mr Ngubane explained the issue of scale used and the different types of data namely raster data and vector data. He explained that in raster data, the resolution is the pixel size of the data. He further explained that the pixel is the smallest unit in which raster data is stored. He explained that if we zoom into a digital image, we eventually see squares. He showed the pictures which were taken at different resolutions to the learners. Mr Ngubane said that vector data is made up of individual points that are saved as coordinate pairs and represent a physical place in the environment. He further explained that in vector data, the format consists of points, lines, or polygons.

Group work as a method

Group work as method, is a learner centred pedagogical approach, and it was mainly implemented in the middle of the lesson, the development stage. Very few teachers used it when teaching GIS topics. Group work was successfully used by Mr Robson and Mr Douglas. Mr Robson who was observed teaching: Components of GIS in grade 10. He successfully used group work by firstly organised his learners in groups of five and he gave them some tasks to do in groups. On this day of the lesson observation, Mr Robson had prepared his lesson thoroughly. He commenced his lesson by recapping the previous section he had taught before and checking the homework he had given to the learners. After the recapping the lesson Mr Robson began by introducing the topic of the day. He showed and explained a few examples of the components of GIS to the class before he asked the learners to go into groups of five. When the learners were in groups, he gave each a worksheet. There were pictures of different types of components of GIS on each worksheet. After issuing the worksheet, Mr Robson instructed the learners to discuss the use of each component and write it down (Table 4.27). His lesson was interactive as learners collaborated with each other discussing each component and sharing their knowledge.

Table 4.27: Example of Group worksheet used by Mr Robson

GIS COMPONENTS	FUNCTIONS/USES
1. People 	
2. Hardware 	
3. Software 	

After giving the worksheet to the learners, Mr Robson walked around checking the progress of the learners and assist the learners who were struggling to understand the use of some of the components of GIS. Mr Robson gave the learners about 15 minutes to the group to complete the task. At the end of 15 minutes, he asked each groups' representative to come up front and report to the class their findings.

The lesson was very interesting and captivating. It kept the learners busy, and it was interactive and constructive lesson. The learners were enjoyed the lesson and participated. At the end of the group work presentation, Mr Robson concluded the lesson by summarising the main concepts taught in that lesson.

Mr Douglas also used group work as an interactive method. I observed him teaching the topic: Data standardisation, data sharing and data security in grade 12. Mr Douglas commenced the class by checking the homework on the previous section he taught on Spatial and attribute data, unit 3 page 43 in Platinum textbook on which they were asked to do Activity 3 on page 45. After checking the learners' homework, Mr Douglas introduced the lesson topic to the learners. Firstly, he explained the main concepts on Unit 4 page 46 in the Platinum textbook. He explained concepts of Data standardisation, Data sharing and Data security. After explaining to the class, he then put the learners into groups of four and asked them to do

Activity 4 in the textbook. He gave the learners 20 minutes to do the activity and afterwards he asked the learners to give the answers to the question. As the learners contribute, Mr Robson add more information to augment what was contributed by the learners.

After the feedback session the teacher wrote some notes on the chalk and asked the learners to copy the notes into their exercise books.

Class discussion as a method

Class discussion as a teacher centred pedagogical approach, was successfully used by Ms Fatima when she was teaching: Application of GIS in grade 11. Ms Fatima used Class discussion pedagogical approach to discuss application of GIS. She made one learner read the case study on page 61 in the Platinum textbook. After reading the case, Ms Fatima guided the class into a discussion on the application and uses of GIS in various sectors of the economy in the country. The class discussion was applied from the beginning of the lesson up to the end and most of the learners were participating in this lesson. At the end of the lesson Ms Fatima asked the learners to do activity 5 on page 62 as their homework. Her lesson was an active approach to learning.

Although Field work and Project assignments as learner centred pedagogical approaches were listed in the questionnaire survey, no teacher was observed using these methods, yet they are signature pedagogies (associated with the discipline) for the discipline of Geography. When the teachers were asked why they did not use methods such as Field work and Project assignment Mr Ngubane stated that:

I cannot use Field work because it requires a lot of time to prepare and it needs a lot of planning, such as finding the suitable study area to go that can educationally benefit the learners and it require money to plan such trips.

Also, Mr van Wyk stated that:

I cannot be able to use Project assignment approach when teaching GIS because I don't have the resources to carry out such assignment. I rely on the geography textbook and I teach what is in the textbook and follow the activities stipulated in the textbook.

The reasons why the teachers were not keen to use Field work and Project assignment was due to lack of resources and time constrains. For instance, Mr Ngubane said that Field work as a pedagogical approach required a lot of planning and requires a lot of time to prepare of which this could not be implemented in a 45-minute lesson. Also, Mr van Wyk echoed the same sentiment that he did not have enough resources to apply such teaching approaches.

He emphasized that he relies on the geography textbook and do all the activities stipulated in the geography textbook.

Overall, the data from the questionnaires, interviews and lesson observation show that most of the teachers used teacher-centred pedagogical approaches to teaching GIS. The main teaching methods that were used by the participants were explaining, questioning, and lecturing. Learner-centred pedagogical approaches were the least used. These approaches include Group work, Class discussion and Project assignment. The participants employed these pedagogical approaches and methods for various reasons. The next section highlights some of the key reasons why the teachers used these ways to teach GIS topics.

4.3.4. RESEARCH OBJECTIVE 4: TO EXAMINE THE REASONS WHY GEOGRAPHY TEACHERS USE THESE PARTICULAR PEDAGOGICAL APPROACHES TO TEACH GIS

This section answers the last objective of this research and the critical question: Why do teachers use these pedagogical approaches to teach GIS? Data gathered from the post lesson interviews basically answers this objective and was answered by responses to Question 3 in Section E of the questionnaire were analysed; the question read:

Can you briefly state the reasons why you choose the methodologies (and approaches) you are using, instead of the other approaches in teaching GIS aspects?

The majority of participants gave various reasons to justify why they used the pedagogical approaches (and methods) they used during the lessons. These reasons are shown on Table 4.28 and discussed on the following section.

Table 4.28: Reasons for using particular pedagogical approaches and teaching methods (data from the lesson observation)

Pedagogical approaches and Methods	Reasons for using the approach
Explaining (TC)	Lack of knowledge Easy to use Familiar
Questioning (TC)	Familiar Less preparation
Lecture method (TC)	Lack of resources It gives teacher autonomy over the class Easy to control and manage the learners Helps to cover a lot of content Less time consuming

Pedagogical approaches and Methods	Reasons for using the approach
	Large classes
Class discussion (TC and LC)	Learners learn from each other, share ideas Learner-centred
Demonstration (TC)	I use this method to show the learners how GIS works So that the learners can understand the concept much better
Practical activity (LC)	GIS needs hands-on experience; I give them some practical activity so that they can see that GIS can solve real life problems
Project assignment (LC)	Learners can learn more when they share ideas It promotes teamwork and corporation

Key:

TC- teacher centred

LC-learner centred

In the next sections I discuss the lack of knowledge by geography teachers and some of the GIS challenges they have which leads them using certain pedagogical approaches only.

GIS knowledge, teacher's profile and pedagogy

Teachers lacked knowledge about GIS as a subdiscipline of Geography, but they also lacked knowledge on how to teach GIS and the best pedagogical approaches to use. The lack of knowledge was for content of GIS (content knowledge) and they also lacked pedagogical knowledge, (knowing what method to use to teach). Teachers used particular pedagogical approaches such as questioning, explanation, lecturing because they lacked GIS knowledge, but this was because of other factors such as age, gender and teaching experience. The majority (84%) of the participants from the questionnaire indicated that they had a fair knowledge of GIS and only 12% stated that they had a good knowledge of GIS, and 4% indicated that they had weak knowledge of GIS (Table 4.28). The cross-tabulation table also reveals that a lack of GIS knowledge cuts across all the age groups that were surveyed. In this case, it shows that lack of knowledge has a bearing on the choice of pedagogical approaches and teaching methods that participants used when they teach GIS. The majority of the participants used explaining, questioning and lecturing methods, because they lacked knowledge on alternative methods of teaching GIS.

Table 4.29: Knowledge of GIS, by age cross tabulation (data from the questionnaire (n=50)

			Knowledge of GIS			Total
			Weak	Fair	Good	
Age	26-29 Years	Count	0	10	2	12
		% of Total	0,0%	83.33%	16.67%	100%
	30-39 Years	Count	1	14	1	16
		% of Total	6.25%	87.5%	6.25%	100 %
	40-49 Years	Count	1	14	2	17
		% of Total	5.9%	82.35%	11.76%	100 %
	≥50Years	Count	0	4	1	5
		% of Total	0,0%	80%	20%	10,0%
Total		Count	2	42	6	50
		% of Total	4,0%	84,0%	12,0%	100,0%

The results of the analysis of the participants' responses to the question that asked them to rate their GIS knowledge, shows that the majority (56%) of them rated themselves as having fair knowledge, while 30% rated themselves weak and 14% rated themselves good. No one rated their knowledge as being good, and this is an important finding as it indicates that the continuum of GIS knowledge for these participants does not extend to the rating of 'good'.

Table 4.30: GIS knowledge, by gender (data from the questionnaire (n=50)

			How do you rate your GIS knowledge?			Total
			Weak	Fair	Good	
Gender	Female	Count	6	8	2	16
		% of Total	37.5%	50%	12.5%	100%
	Male	Count	9	20	5	34
		% of Total	26.47%	58.82%	17.70%	100%
Total		Count	15	28	7	50
		% of Total	30,0%	56,0%	14,0%	100,0%

Teachers' knowledge of GIS was also compared against gender. The results of the analysis on knowledge, show that the majority (56%) of the teachers rated themselves as having fair knowledge, while 30% rated themselves weak and 14% rated themselves good in relation to knowledge of GIS.

The two cross-tabulation tables show that most of the participants, who all teach geography, lack GIS knowledge. This lack of GIS content knowledge among the geography teachers affected their choices of pedagogical approaches. The participants, however, cited various reasons for this lack of knowledge, including that they had not received adequate training on GIS. They mentioned that they had attended only one workshop on GIS, which had been provided by the provincial education department. The majority of the participants reported this training as inadequate. Therefore, they resorted to making learners memorise answers to the GIS exam section.

Lack of teaching resources

The other reason which was highlighted by the majority of the teachers who were surveyed and interviewed was a lack of teaching resources. These resources ranged from textbooks, GIS software, GIS laboratories, GIS data, topographic maps and in some schools especially in township and rural schools was lack of furniture. These challenges have a bearing on the choice of pedagogy a teacher would select when teaching GIS. To start with, the majority of the teachers (80%) (n=8), used a teacher-centred approach for their teaching. The main approaches they used were explanation, questioning, lecture and class discussion. Very few teachers used learner-centred pedagogical approaches, such as group discussion and class discussion. Seven schools I visited did not have computer laboratories, data projectors or stand-alone geography classrooms. Teachers who teach different subjects share the same classrooms. The teachers also cited lack of internet connections at most schools. The schools that offer Computer Assisted Technology (CAT) as a subject are the only ones that have computer laboratories. However, conducting geography lessons in the laboratories was not feasible, because the laboratories are always locked to prevent damage, and generally management and CAT teachers do not want to share the laboratories with teachers who teach other subjects. No teacher was observed using fieldwork and projects as pedagogical approaches to teach GIS.

Large classes

Mr Ngubane, at School 10, used the lecture method and he stated the following reasons, after being asked why he used that approach:

There are 55 learners in the class; using group work takes time, and managing the learners is tough when there are so many and not enough textbooks.

Mr Ngubane raised a lot of challenges which affected many teachers in many secondary schools in the province. Many teachers in the study area are grappling with large classes which make it difficult for them to choose a learner-centred pedagogical approach. In his response, Mr Ngubane stated that he uses the lecture method because arranging larger numbers of learners into groups is time consuming and the class would become difficult to manage, so he opts for a passive method. Also, he raised the issue of a lack of textbooks as the other reason why he resorted to the lecture method in teaching.

A lack of resources

Mr Rua at School 8 cited lack of physical resources at his school. He stated that:

I cannot use fieldwork or any other teaching strategies because I don't have resources such as computers which promote hands-on experiences and learner-centred learning.

During the class observation, Mr Rua only used the explanation and questioning to teach the concept of GIS components. Very few learners participated in this class.

Mr Van Wyk used a number of pedagogical approaches. He used the questioning, explaining, and demonstrating. He also used resources that were available, such as cell phone, to demonstrate the concept of resolution. When he was asked about his reasons for doing so, the teacher said:

As a teacher one has to be innovative and make the lesson more interesting. Learners of today love technology and as a teacher you have to satisfy their needs in one way or the other.

Finally, Mr Douglas at School 6 used group work. He divided the learners into groups and asked them to trace different layers from topographic maps. The lesson was learner-centred from the beginning to the end. His answer to the question about why he used that approach was as follows:

GIS concepts are difficult to understand, if one wants learners to understand the concept, learners have to do it practically. In this way they will not forget the concept.

The majority (70%) of the teachers stated that they use direct instruction, such as explaining, questioning and lecturing for various reasons. During the lesson observation I noted that teachers did not adhere to one method. In most instances, the teachers used two or three methods at different stages of the lesson development. The reasons for using different methods are summarised in Table 4.28. The teachers also stated that they used the lecture method because it gives them control over the learners they teach, and they will be in a position to instil discipline in the class.

In conclusion of this section, the majority (80%) of the teachers used a teacher-centred approach to deliver their lessons. The teachers cited a lack of time and a lack of physical resources and large classes as some of the reasons why they used such approaches. For instance, the majority of the teachers were using a teacher-centred pedagogical approach. The most commonly used teaching methods include the lecture method, demonstration[4] and class discussions. The teachers highlighted the following challenges they face in schools:

GIS Challenges by type of school

The results in Table 4.29 show that the percentages of those who believe that GIS needs hands-on experience are moderate for both private (50%) and public schools (61%) and the two percentages are not significantly different (W=148.5, p-value=0.886).

Table 4.31: Cross-tabulations of GIS challenges by type of school.

GIS Challenges		Type of school		Wilcoxon's_W tests	
		Private	Public	W	p-value
GIS needs hands-on experience	Neutral	3	17		
	Agree	1	16	148.5	0.886
	Strongly agree	2	11		
	%agree/strongly agree	50%	61%	**No Significant difference in mean ranks**	
	Mean rank	24.75	25.60		
GIS needs more time to teach and learn	Neutral	2	10		
	Agree	2	16	137.0	0.610
	Strongly agree	2	18		
	%agree/strongly agree	67%	77%	**No Significant difference in mean ranks**	
	Mean rank	22.83	25.86		
GIS technology is hard to learn and to teach	Neutral	2	11		
	Agree	3	15	122.5	0.332
	Strongly agree	1	18		
	%agree/strongly agree	67%	75%	**No Significant difference in mean ranks**	
	Mean rank	20.42	26.19		

As far as the view that GIS needs more time to teach and learn is concerned, there was a moderately high level of agreement among the respondents from the two types of schools (67% for private and 77% for public schools) and the two groups do not significantly differ

[4] The term "demonstration" relates to a certain activity or concept that is given or performed. The demonstration technique is used to carry out the teaching-learning process in a systematic manner. When learners are having problems learning a concept or integrating theory to practice, it is frequently used (Ekeyi, 2013).

(W=137.0, p-value=0.610). These sentiments are similar on the view that GIS technology is hard to learn and to teach (67% for private and 75% for public schools).

GIS challenges by teaching experience of teachers.

Table 4.32 shows that across levels of teaching experience, the percentages of those who believe that GIS requires hands-on experience range from moderate to high. However, the differences in the percentages across the different levels of participants were not statistically significant (χ^2=3.979, p-value=0.264).

Table 4.32: Cross-tabulations of GIS challenges by teaching experience of teachers.

GIS Challenges		Teaching Experience				Kruskal-Wallis Test		
		0-4 years	5-9 Years	10-14 years	15 Years	χ^2	df	p-value
GIS needs hands-on experience	Neutral	7	3	9	1			
	Agree	3	5	8	1	3.979	3	0.264
	Strongly agree	2	3	5	3			
	%agree/strongly agree	41.7%	72.7%	59.1%	80.0%	No Significant difference in mean ranks		
	Mean rank	20.71	28.05	24.84	34.30			
GIS needs more time to teach and learn	Neutral	2	1	8	1			
	Agree	6	5	6	1	1.921	3	0.589
	Strongly agree	4	5	8	3			
	%agree/strongly agree	83.3%	90.9%	63.6%	80.0%	No Significant difference in mean ranks		
	Mean rank	25.33	28.77	22.95	29.90			
GIS technology is hard to learn and to teach	Neutral	2	3	5	3			
	Agree	3	3	11	1	4.051	3	0.256
	Strongly agree	7	5	6	1			
	%agree/strongly agree	83.3%	72.7%	77.3%	40.0%	No Significant difference in mean ranks		
	Mean rank	30.71	26.68	24.02	16.90			

As far as the view that GIS needs more time to teach and learn, there was a high level of agreement among the respondents from all levels of teaching experience and there were no statistically significant differences (χ^2=1.921, df=3, p-value=0.589). However, this finding contradicted with results from the interviews and the lesson observations. Most of the teachers interviewed especially the older (over 50 years) teachers stated that they were facing numerous challenges when teaching and assessing GIS topics. Also, the lesson observations confirmed that indeed the teachers were under trained in GIS teaching and learning. Only a few young teachers who had recently (0-2 years teaching experience) joined the teaching profession were comfortable with the teaching of the topics of GIS in former model C schools (now incorporated into public schools) and private schools. This was due to GIS modules not being part of their teacher training in universities and colleges of education.

Table 4.33: Cross-tabulations of GIS challenges by age.

GIS Challenges		Age				Kruskal-Wallis Test		
		26-29 Years	30-39 Years	40-49 Years	50+ Years	χ^2	df	p-value
GIS needs hands-on experience	Neutral	8	5	4	3			
	Agree	2	9	5	1	6.659	3	0.084
	Strongly agree	2	2	8	1			
	%agree/strongly agree	33.3%	68.8%	76.5%	40.0%	**No Significant difference in mean ranks**		
	Mean rank	19.17	25.09	31.71	20.90			
GIS needs more time to teach and learn	Neutral	5	3	3	1			
	Agree	3	7	6	2	1.488	3	0.685
	Strongly agree	4	6	8	2			
	%agree/strongly agree	58.3%	81.3%	82.4%	80.0%	**No Significant difference in mean ranks**		
	Mean rank	21.58	25.81	27.79	26.10			
GIS technology is hard to learn and to teach	Neutral	3	7	2	1			
	Agree	1	3	11	3	2.774	3	0.428
	Strongly agree	8	6	4	1			
	%agree/strongly agree	75.0%	56.3%	88.2%	80.0%	**No Significant difference in mean ranks**		
	Mean rank	30.96	22.66	25.03	23.10			

As far as the view that GIS needs more time to teach and learn is concerned, there was a high level of agreement among the respondents from all age groups and there were no statistically significant differences (χ^2=1.488, df=3, p-value=0.685). The same applies to the view that GIS technology is hard to learn and to teach and there were no statistically significant differences across the age groups (χ^2=2.774, df=3, p-value=0.428).

GIS Challenges by race

The results in Table 4.34 show that the percentages of those teachers who believe that GIS needs hands-on experience range from low to moderate across racial groups with white teachers of the view that GIS does not need hands-on experience, so the white teachers in this research seem to be more aware of GIS technology than the other race groups. This suggests that they were facing less challenges as compared to other races. This is because the schools populated by Whites in South Africa remain more privileged than schools populated by other races. However, the differences in the percentages across race were not statistically significant (χ^2=1.085, df=2, p-value=0.581). This observation was also shown in the interviews and lesson observations. Most the teachers who were trying to integrate GIS were White teachers and teaching in former C model and private schools. These schools are well resourced, and they can afford internet connectivity. For instance, Mr Robson who taught at a private school had QGIS software on his laptop and he was able to integrate GIS in his geography lesson. Also, it was observed that most of the white teachers were teaching in less crowded classrooms when compared to other race groups and this perhaps accounts for their positive attitude and view of GIS.

Table 4.34: Cross-tabulations of GIS challenges by race.

GIS Challenges		**Race**			**Kruskal-Wallis Test**		
		Black African	White	Coloured	χ^2	df	p-value
GIS needs hands-on experience	Neutral	11	4	5			
	Agree	8	2	7	1.085	2	0.581
	Strongly agree	9	1	3			
	%agree/strongly agree	60.7%	42.9%	66.7%	**No Significant difference in mean ranks**		
	Mean rank	26.55	20.57	25.83			
GIS needs more time to teach and learn	Neutral	7	2	3			
	Agree	9	3	6	0.359	2	0.836
	Strongly agree	12	2	6			
	%agree/strongly agree	75.0%	71.4%	80.0%	**No Significant difference in mean ranks**		
	Mean rank	25.89	22.64	26.10			

GIS technology is hard to learn and to teach	Neutral	7	3	3			
	Agree	11	3	4	2.979	2	0.226
	Strongly agree	10	1	8			
	%agree/strongly agree	75.0%	57.1%	80.0%	**No Significant difference in mean ranks**		
	Mean rank	25.23	18.50	29.27			

As far as the view that GIS needs more time to teach and learn was concerned, there is high level of agreement among the respondents from all races, the percentages are not significantly different (χ^2=0.359, df=2, p-value=0.836).

The view that GIS technology is hard to learn and to teach had a lower level of agreement among the Whites (57.1%) than the other two racial groups who seemed to be struggling more with the teaching of GIS topics (75.0% for blacks and 80.0% for coloureds). However, there were no statistically significant differences across the races (χ^2=2.979, df=3, p-value=0.226). The geography teachers who were White who participated in this research have a low level of agreement on this variable and it may be is due to them teaching in more privileged schools (as a result of historical privilege based on race) where they are more exposed to the new technology than the other two races where schools have still not de segregated .African black and coloured teachers still teach in the same disadvantaged schools plagued by poverty and other challenges such as a lack of technological infrastructure. Mr Ngubane who teaches in a rural school highlighted some of the challenges he was facing. He stated:

My main challenge at this school concerning GIS teaching is lack of textbooks, no GIS lab and software, lack of topographical maps. My geography classes overcrowded and some of the learners do not have chairs and desks.

Mr van Wyk who taught at a school with coloured learners also highlighted a shortage of teaching and learning materials. He stated the following:

Many geography classes are large and at times the textbooks are not enough especially in the grade 10 classes.

GIS Challenges by gender

The results in Table 4.35 show that there was a statistically significant difference between males and females in the perception that GIS needs hands-on experience (W=398.0, p-value=0.824). The level of agreement on this matter was moderate (62.5% for females and 58.8% for males).

Table 4.35: Cross-tabulations of GIS challenges by gender.

GIS Challenges		Gender		Wilcoxon's W tests	
		Female	Male	W	p-value
GIS needs hands-on experience	Neutral	6	14		
	Agree	7	10	398.0	0.824
	Strongly agree	3	10		
	%agree/strongly agree	62.5%	58.8%	**No Significant difference in mean ranks**	
	Mean rank	24.88	25.79		
GIS needs more time to teach and learn	Neutral	4	8		
	Agree	5	13	858.0	0.841
	Strongly agree	7	13		
	%agree/strongly agree	75.0%	76.5%	**No Significant difference in mean ranks**	
	Mean rank	26.06	25.24		
GIS technology is hard to learn and to teach	Neutral	5	8		
	Agree	4	14	863.0	0.929
	Strongly agree	7	12		
	%agree/strongly agree	68.8%	76.5%	**No Significant difference in mean ranks**	
	Mean rank	25.75	25.38		

On the statement that GIS requires more time to teach and learn, the results showed that 75% of female teachers and 76.5% of male teachers believed that GIS needed more time to teach and learn by the teacher and the two groups do not significantly differ in their assessment (W=0.858.0, p-value=0.841).

The view that GIS technology is hard to learn and to teach had moderately high levels of agreement among the female teachers (68.8%) and the male teachers (76.5%) and the two groups did not differ significantly (W=863.0, p-value=0.929 This means that both male and female teachers experienced similar challenges. This was also confirmed by the findings from the lesson observations. In some schools, I observed 4 out of 7 schools in the township had not enough furniture and textbooks. Also, 2 out of 3 schools visited in rural areas had not enough furniture and textbooks and there was no electricity connectivity. The challenges faced by teachers in private and former C Model schools were a lack of internet connectivity and the lack of time to prepare GIS lessons. The main challenges faced by teachers in township and rural schools were large classes, a lack of textbooks, a shortage of infrastructure, a lack of GIS training, teachers' lack of GIS knowledge and skills to teach GIS topics.

Lack of GIS resources

Another finding which strongly came out of this research from all the three tools used is lack of GIS resources in schools. Almost all the teachers stated that they do not have adequate GIS resources. As a result of the shortage of GIS resources teachers depends on textbooks which are not even enough for every learner in some schools more especially in township schools and rural schools. In some townships, learners were observed fighting for the few textbooks which were available, and this compromised discipline and learning during GIS teaching. Classes which lacked enough textbooks were characterised by noise and rowdy learners. The lack of GIS resources had a bearing on the choice of pedagogical approaches and methods which the teachers were eventually implementing when teaching GIS. The research revealed that most of the teachers used a teacher-centred pedagogical approach which guaranteed maximum classroom control of the learners as a way of trying to instil discipline in the classroom. Teachers were seen engaging in chalk and talk teaching, lecturing, explaining and questioning techniques due to shortages of GIS resources do not promote subject-specific skills as stipulated by the CAPS document. These types of methods instil rote learning whereby the learners are supposed to memorises and reproducing the answers without engaging in critical thinking and problem solving which is one of the skills that geography and GIS is supposed to promote and inculcate in learners. In many lessons observed in this research, teachers were seen making learners memorise answers without deep learning taking places in the lesson. For instance, Ms Mable who was observed teaching Querying and Statistics Analysis to grade 12 by simply reading from the textbook and this was insufficient for the learners to acquire skills as stipulated in the Geography CAPS document. When I probed Ms Mable further on her teaching methods and approach, she highlighted that she did not have enough GIS resources to teach the topic and hence she did the best she can to '*assist the learners to at least learn something'*.

Inadequate GIS information in the textbooks

The other challenge that teachers face is inadequate information on GIS in the textbooks which teachers are using in high school. The GIS information that is in the textbook is not adequate to equip the learners to be critical thinkers and able to solve spatial problems.

Fieldwork was recommended as one of the major teaching approaches teachers should use when teaching GIS topics in the CAPS document, but not a single teacher was observed using this approach. The CAPS document stated unequivocally that Fieldwork should be used where learners in grades 10-12 are supposed to be taught the following skills:

- Data collection and recording using a variety of techniques, including the use of weather instruments and gathering weather information from the media.

- Using line graphs, bar graphs, charts, diagrams, and synoptic weather maps to compile, interpret, and present fieldwork findings.
- Data collection and recording,
- Data processing, collation, and presentation of fieldwork findings,
- Data collection and recording using a variety of techniques,

Fieldwork findings are processed, compiled, and presented (DoE, 2011). The shortage of content in geography and GIS in many textbooks used in high schools was also highlighted by Manik & Malahlela (2018) in their research (about the use of geography textbooks) which was done in the Eastern Cape and KwaZulu-Natal.

4.4 CONCLUSION

The findings of the study, which addressed the four research questions, were presented and discussed in this chapter. This chapter examined the profile of the geography teachers who participated in this research, and then reported findings of the questionnaire, interviews and lesson observations. The findings reported on teachers' attitudes and perspectives on the incorporation of GIS into the geography curriculum. It also presented the findings of the pedagogical approaches and teaching methods used by the teachers when they teach GIS. Finally, the chapter presented the reasons why the teachers choose to use the pedagogical approaches and teaching methods which they use to teach GIS and the challenges they face in general.

In this chapter, the attitudes and views of sixty geography teachers from state and private schools in the Frances Baard District of the Northern Cape province were examined. According to the research findings, the following summary of the results can be concluded: nearly all of the teachers in this study stated that their schools do not have computer laboratories or GIS software. The study also discovered that the majority of participants (70 percent) had a favourable attitude toward the incorporation of GIS into the geography curriculum. The main view that emerged from this study was that GIS promotes learner-centred teaching and deep learning. Their views were that GIS enables learners to develop inquisitive minds and think critically and assist them to solve problems. There was no significant difference in geography teachers' views towards GIS according to variables such as "gender" and "race". all teachers were of the view that they wanted more GIS training. Teachers who were relatively younger were more comfortable in teaching GIS topics than older teachers. The younger teachers were able to engage the learners easily and learners co-operated and participated during lessons. The majority of those who took part in this study had a favourable attitude toward the incorporation of GIS into the geography curriculum. There were very few participants who had negative attitudes toward GIS.

Many of the participants used multiple pedagogical approaches when teaching GIS. The main pedagogical approach used by the teachers was teacher-centred, which included direct instruction, such as explanation, questioning and lecturing. Very few teachers in this research used learner-centred pedagogical approaches, such as group work, fieldwork, project assignments, collaborative problem-solving and the experimentation method.

The participants in this research highlighted a number of challenges. They cited large classes as one of the challenges. Teachers who teach in schools located in rural areas and in townships stated larges classes, lack of teaching material, lack of training in GIS as the major challenges. On the other hand, teachers who teach in former Model C schools and in private schools cited challenges such as lack of internet connectivity, shortage of GIS software and limited time to teach geography and GIS in general. The teachers located in private and former Model C schools were able to integrate more teaching methods when teaching GIS content than the teachers who teach in schools in the townships and rural areas.

CHAPTER 5: DISCUSSION OF FINDINGS

5.1 INTRODUCTION

The main thrust of this chapter will be to link the findings from the quantitative and qualitative data sets with the literature reviewed in Chapter 2 with the aim of extending the existing knowledge and building theory on the diffusion of GIS in township and rural schools. The chapter commences with a discussion linking the findings on teachers' professional qualifications and teaching experience, attitudes, and views of the teachers with the literature on the teacher pedagogical approaches used to teach GIS. Finally, the chapter discusses the reasons why the participants employed the pedagogical approaches they did for delivering their lessons. Collectively the discussion provides greater insights into understanding the diffusion of GIS in township and rural schools. Through the discussion of the findings and themes of this study, the research provides some recommendations that offer guidelines on how GIS can be taught in high schools in these contexts in SA. In this way, the study has sought to contribute to the knowledge on the implementation of this new curriculum addition, GIS, into geography in high schools.

5.2 OVERVIEW OF THE STUDY

The introduction of GIS as a section in the geography FET curriculum and its diffusion in classrooms has been met with many challenges. GIS was introduced in geography in the last decade and the research on how it is being taught and used by teachers in the classroom is still very limited. Also, the pass rate in the GIS section of the exit examination in grade 12 is worrying (Zuma, 2016; Zondi & Tarisayi, 2020; Mkhongi & Musakwa, 2020). The discussions that follow are in accordance with the critical questions of this research. These research questions are:

What are teachers' attitudes towards GIS in geography in the FET curriculum?

What are the teachers' views about GIS in geography in the FET curriculum?

What are the pedagogical approaches used to teach GIS?

Why do teachers use these pedagogical approaches to teach GIS?

The discussion leans on the conceptual framework presented in Section 2.8 and the discussion in the literature review in Chapter 2. The findings will be discussed using the lens of the two theories relevant for this study: DOI (Rogers, 2003) and TAM (Legris, 2003). The study concludes with salient insights on GIS diffusion in the Frances Baard district and recommendations for future research in this phenomenon.

5.3 TEACHERS' QUALIFICATIONS AND SUBJECT SPECIALISATION

The literature reviewed revealed that there is a link between teachers' qualifications, subject specialisation and how the content is framed and taught to the learners (Burroughs et al., 2019).

All 60 teachers (50 who completed the questionnaire survey and 10 who were interviewed) had university degrees (Table 4.4 & Table 4.5) and they were experienced teachers; majority of the teachers had been in the teaching profession for more than two years. Teacher qualifications have an important role in the quality of geography teaching and in particularly GIS because teachers teach better if they have content knowledge of the subject (Oshima, 2015; Guerriero, 2017). GIS is a technology and there is a practical component to teaching it that is required. Teachers who had graduated specialising in geography were better in teaching geography than those teachers who had acquired specialisations in other subjects such as history and the languages. This was revealed in this research. Some teachers(n=3) who specialised in geography, mathematics and technology respectively were successful in teaching GIS in the grades they were observed teaching. Mr Tau and Ms Fatima employed a variety of teaching approaches which benefited learners in understanding the topics they were teaching. Learners freely participated, asking questions, and providing explanations that contributed to the construction of knowledge during the lesson. It must be noted that there is some evidence in the literature linking learners' achievement to teachers' specialisation. Available research about a fourth grade reading achievement in Sweden revealed that there was a positive relationship between teachers' specialisation in the subject and the achievement of learners (Johansson & Myrberg, 2019; Myrberg, Johansson, & Rosén, 2019). Also, research by Rockoff (2004) suggests that raising teacher quality through training and academic qualifications may be a key instrument for improving learner outcomes. Davis (2009) and Fred & Tamale (2013) assert that teachers' qualifications do have a positive relationship with learner achievement and performance in the classroom. This was evident in this research, with some teachers (n=2) whose pre- service training at universities included GIS modules which provided them with the ability to explain some GIS concepts in greater depth when compared to those teachers who did not have the opportunity to do GIS as part of their preservice training. According to Owolabi and Adedayo (2012), learners who are taught by higher-qualified teachers outperform those who are taught by lower-qualified teachers. This finding from the literature did not come out clearly in this research because the focus of the study here was not on learner performance but rather on teachers.

Nevertheless, most teachers who had high qualifications and vast teaching experience in geography were struggling to teach some topics in the following GIS sections: “spatial and spectral resolution, data manipulation and application and GIS techniques, data standardisation and data sharing and data security, data integration; buffering; querying, and statistical analysis” (in grade 12). Research by Omolara (2015) on the attitudes of teachers towards Social Studies revealed that the lack of content knowledge affects teachers’ attitudes towards the subject they teach. GIS is a challenging field because of its specialised knowledge which requires well trained and skilled teachers. The literature reviewed and the findings from this research revealed that most of the available teachers in geography are not competent enough to teach GIS in the CAPS (Mzuza & van der Westhuizen, 2019; Zondi & Tarisayi 2020; Mkhongi & Musakwa, 2020). If the teachers lack content knowledge, such teachers will be unable to give detailed explanations about the concepts or provide meaningful understanding. Omolara (2015) reveals that this will also affect learners’ performance in the subject, causing a loss of interest in the subject.

The current research found that relatively younger novice teachers who had joined the teaching profession recently were found to be more confident in the classroom when teaching GIS topics from the CAPS than relatively older teachers who had numerous years of teaching experience in geography. These same sentiments were echoed by Thompson (2014), who does, point out that qualification alone is not a guarantee of good teaching. Also, research from Limpopo, South Africa by Maphoso and Mahlo (2015) found that teachers’ qualification is not the only contributor in the learner’s academic achievement. Teachers must know how to organise their classes and their lessons in a manner that will help learners to learn effectively, thus general pedagogical knowledge is also critical. Thompson (2014) argues, furthermore, that highly qualified teachers do not necessarily teach better than less qualified teachers. The findings of this research concur with the findings of Thompson (2014). Mr Ngubane, a university graduate with over 25 years of teaching experience and specialising in history, geography, and languages, pointed out that GIS topics were new, and they thus presented a challenge to him. Mr Ngubane (I, 1a) admitted that, despite his high academic qualifications and vast teaching experience, he found GIS topics difficult to teach because GIS is a new inclusion in the geography FET syllabus. Mr Ngubane bemoaned that he did not have the opportunity to learn it when he was doing his training at university because during that time module(s) on GIS were not being offered. This finding concurs with the literature consulted in this research. For example, Mzuza and van der Westhuizen's (2019) research on the state of GIS education in Southern African countries discovered that, while GIS is included in many African countries' education curricula, some countries are still lagging in terms of implementing GIS as a teaching tool in many secondary schools, colleges, and universities.

Mzuza and van der Westhuizen (2019) added that, despite significant progress in GIS education, many African learning institutions continue to face difficulties in the development and use of GIS as a teaching and learning tool. For instance, Rwanda is regarded as one of the countries that has made significant progress in GIS education, but it still faces numerous challenges, such as a scarcity of experienced GIS teachers, a lack of electricity, and shortage of computers in schools Mzuza and van der Westhuizen (2019, p. 5)

In the current research, younger teachers (26-49 years) were better than older teachers (over 50 years) and were more innovative when it came to teaching GIS. Mr Tau (40-49 years) who was observed teaching the components of GIS to grade 10, brought different components of GIS (such as laptop, GPS instruments, CDs. Maps) to the class, to demonstrate to the Grade 10 learners what he was teaching. His lesson was very successful, because he was able to use the available physical resources to teach GIS components. Mr Tau had mastered the content knowledge and he used demonstration and explanation as teaching methods to create a successful GIS lesson. When Mr Tau was further probed to find out about his qualification and teaching experience, the results showed that Mr Tau specialised in Geography and Technology, which has relevance for teaching GIS and studying GIS was part of his preservice teacher training.

5.4 TEACHING EXPERIENCE IN GIS

The number of years a teacher has been in a classroom teaching is referred to as their teaching experience (Burroughs et al., 2019). Many studies have found a link between teaching experience and learner achievement (Burroughs, et al., 2019). There is a strong link between teaching experience and learner achievement, particularly among secondary learners (Rice, 2003; Papay & Kraft, 2015; and Ladd & Sorenson, 2017). Although there is a clear link between teaching experience and learner achievement, other research has found no consistent and substantial connections between learner achievement and instructor experience. (Wilson & Floden, 2003; Luschei & Chudgar 2011; Blomeke et al., 2016; Gustafsson & Nilsen, 2016). All 60 teachers who participated in this current study had extensive teaching experience in geography but little experience in teaching GIS because it was a new curriculum addition in high school geography. Their years of teaching experience in geography was not enough to bolster confidence and to demonstrate that they were successful in teaching some of the GIS topics. This finding confirms the contradictions in the literature. The limited GIS teaching experience is due to GIS being introduced in the geography curriculum 14 years ago but its relatively slow diffusion since then. In South Africa, GIS was introduced at the Grade 10 level in 2006. In an incremental fashion it expanded to Grade 11 in 2007 and Grade 12 in 2008. The years of experience of the teachers interviewed and through the questionnaire are summarised in Table 4.3a &b. Despite all the years of teaching experience, all 10 teachers who were interviewed, agreed that GIS was difficult to teach without computers, and that its newness in the curriculum made it difficult to teach given the lack of adequate training. Mr van Wyk, Mr Ngubane and Ms Fatima who were the most experienced teachers in geography stated that teaching GIS was difficult as it was a newly introduced section centred on technology innovation and thus it required specialised teacher training. Age, gender, and race had no association regarding the use and teaching of GIS in the schools in this study. The literature on GIS confirms this finding (Siegmund, Volz & Viehrig, 2007; Mzuza & van der Westhuizen, 2019; Mkhongi & Musakwa, 2020). GIS topics in the curriculum were new, and they were introduced into the geography curricula of most countries recently. Some African countries such as Ghana, Swaziland and Mozambique do not teach GIS in both high schools, and colleges/ universities where teachers obtain their training (Fleischmann & van der Westhuizen, 2020). In countries where GIS is included in high school curricula, such as the Democratic Republic of the Congo and South Africa, it is not fully taught as a practical subject in schools (Mzuza & van der Westhuizen, 2019), implying that there are significant pedagogical gaps in GIS education.

5.5 TEACHER PROFESSIONAL DEVELOPMENT IN GIS

As briefly alluded to above, most of the teachers in this present study did not have training in GIS. They had only attended a few workshops, which were administered by the Department of Basic Education. According to the findings of this study, the majority of teachers believed they were ill-equipped to teach it. The findings from the questionnaires and interviews in the current study also confirm that the workshops were inadequate. The majority (85%) of all the teachers who participated in this research stated that the workshops which were rolled out by the Department of Basic Education in the province were not enough nor sufficiently detailed for them to learn about GIS and how to use it in the classroom. Majority of the teachers bemoaned that the workshops were only aimed at targeting the grade 12 teachers since the matric results in GIS workshops were foregrounded by the officials from the department of education and less time was allocated for GIS training of the teachers who attended. This inadequate in-service training in GIS and the lack of GIS knowledge was also observed in the lessons. I noted that the majority (n=8) of the teachers struggled to explain some of the concepts of GIS they were teaching such as buffering, resolutions, attribute tables and querying. Such critical concepts of GIS are best explained when the teachers are doing it practically with examples using the computer so that the learners can see what is meant by buffering and querying. Abstract explanations without engaging the other sensory modes of a learner such as the sense of sight and touch would make such concepts difficult to understand without applying the other senses which might help the learners to learn and gain a better understanding of the concepts being taught. It is argued that learning is improved when learners can see and experience what they are being taught (Shabiralyani, Hasan, Hamad & Iqbal, 2015).

The recent introduction of GIS in the high school geography curriculum is not unique to South Africa. In Rwanda, GIS was introduced in the high school geography syllabus in 2008 in a snowball fashion. There, 30 teachers from 10 pilot schools were trained to teach GIS in the classroom (Akinyemi, 2015). The teachers were selected according to how many working computers they had at their schools. The teachers who had been selected taught 500 learners in total at these schools. After receiving the training, the teachers were expected to teach other teachers in their neighbourhoods. Through this snowball dispersion model, more teachers were trained in this way (Forster & Mutsindashyaka, 2008; Akinyemi, 2015). The teaching and training model in South African schools regarding GIS is different as teachers were workshopped on GIS by the Department of Education and left without further mentorship /support or necessary equipment for example, GIS laboratories, technical support and equipment to empower the teachers. In Rwandan high schools, GIS is taught practically in the GIS lab. In South African high schools, GIS is not taught practically and is not tested practically either. Learners are theoretically tested (the CAPS clearly states a ‘paper GIS’) and the practical aspect of GIS is neither stated nor required to be tested in the exit examination of grade 12.

5.6 LACK OF GIS KNOWLEDGE

According to Rogers' (2003) theory of technology diffusion, DOI occurs through a five-step decision-making process. It takes place through several communication channels over time among similar members of a social system. The processes include exposure to technology, where the stakeholders acquire the knowledge before, they can adopt the technology. After acquiring knowledge, the stakeholders need to be convinced/persuaded that the innovation/technology will be beneficial to them – this relates to the changing attitudes of people who will be implementing the technology. Once the appropriate attitudes have been established, stakeholders will be able to decide whether or not to use and integrate the technology. People's attitudes toward a new technology are critical factors in its spread (Rogers, 1995). However, while people's attitudes toward the adoption of new technology are important, the findings of this current study show that it is far more complex than the teachers' positive attitudes (Figure 5.1). The adoption of technology in teaching and learning, particularly GIS, is influenced by the interaction of various factors. According to Hew and Brush (2007), there are four types of impediments to technology adoption in schools namely, a lack of resources, insufficient knowledge and skills, institutional barriers, attitudes and beliefs, assessment, and subject culture. Mumtaz (2000) identified numerous elements that influence teachers' decisions and attitudes about adopting ICT in the classroom, focusing more closely on instructors. Lack of resources, software and hardware quality, technological ease of use, incentives to change, support and collegiality in their schools, school and national policies, commitment to professional learning, and a background in formal computer training are among them. This current research identified a marriage of several factors that hinder and negatively affect the diffusion of GIS in the geography classroom in high schools and these factors are discussed on the following section.

5.7 INHIBITING FACTORS FOR GIS DIFFUSION- IN HIGH SCHOOLS IN FRANCES BAARD

The Model (Figure 5.1) presented highlights the multitude of overwhelming factors that disable GIS technology diffusion in schools in Frances Baard district. The teachers interviewed, had their lessons observed in both rural and urban areas. Teachers in rural schools identified the lack of electricity and internet connectivity as key factors that disable GIS in terms of its diffusion. Besides the factors highlighted in the DOI and TAM, Figure 5.1 highlights other salient factors which were identified as disabling factors for GIS diffusion in schools in Frances Baard high schools. Lack of a GIS laboratory, GIS software, internet connectivity, a lack of GIS content knowledge by teachers, large classes, and teachers' views that GIS is difficult to learn (see Figure 5.1) are some of the disabling factors that cut across all schools in the study area.

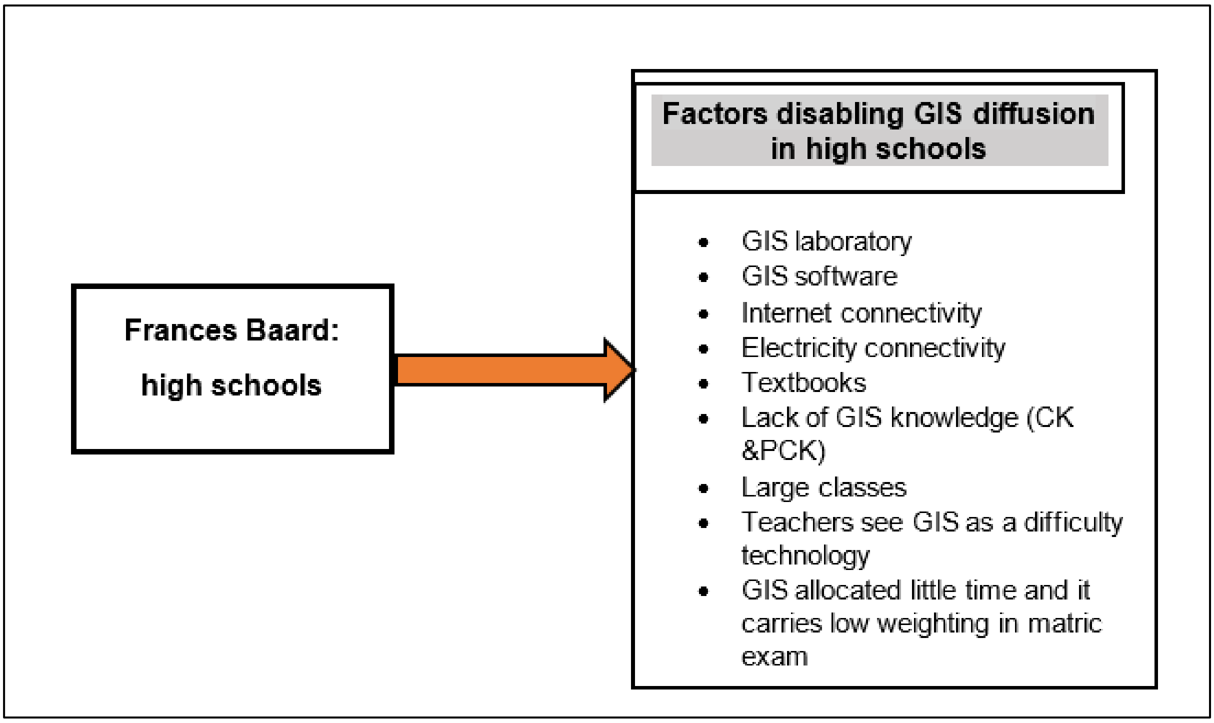


Figure 5.1: The model of disabling factors of GIS diffusion in schools.

As mentioned in Chapter 2, Roger's theory of innovation spread involves five steps: "information, persuasion, decision, implementation, and confirmation." (Sahin, 2006, p.15) The factors of perceived ease of use, perceived utility, and technology acceptance were underlined by TAM (Ma & Liu, 2004; Deslonde & Becerra, 2018). The findings of this current research showed that there are other disabling factors to technology diffusion (Figure 5.1). The findings from this study's classroom observations revealed that a lack of GIS laboratories and software, internet access, and a lack of GIS content understanding and pedagogical content knowledge (Figure 5.1) are some of the biggest stumbling blocks to GIS adoption in schools. The research also found that the teachers were of the view that GIS technology promotes learner-centred teaching and enhances spatial thinking and problem-solving in learners. However, most of the teachers surveyed in this research were of the view that GIS is difficult to learn and difficult to teach without GIS resources: laboratories and GIS software.

5.7.1 LACK OF A GIS LABORATORY AND GIS SOFTWARE

GIS concepts are better understood by learners when they are taught practically in a GIS laboratory. GIS topics are taught theoretically in geography in most high schools in South Africa. Teachers find this section of geography difficult to teach. This inhibiting factor of GIS equipment is not only unique in schools in Frances Baard district in Northern Cape in South Africa. Mzuza and van der Westhuizen (2019) found that a lack of GIS infrastructure, such as computers and GIS software, as well as a lack of GIS expertise, are constraining factors in GIS diffusion in secondary schools in the southern African region.

5.7.2 LACK OF ELECTRICITY AND INTERNET CONNECTIVITY

The other disabling factor of GIS diffusion in rural schools was a lack of electricity, a lack of internet connectivity and a perceived difficulty of the GIS technology. Ms Fatima who was teaching at a rural school complained about a lack of electricity and internet connectivity in the school. The lack of electricity and internet connectivity is not unique to South African schools. Buabeng-Andoh (2012) discovered that electricity and internet connectivity have a negative impact on the diffusion of technology such as GIS in a study on the factors that influence teachers' use and integration of information and communication technology in the classroom in Ghana. Computers are powered by electricity and thus if a school is not connected to the national grid, it is very difficult for teachers to use computers. Also, the lack of internet connectivity was highlighted as one of the major disabling factors in GIS diffusion. Some schools, both in cities and in rural areas, are not able to download some useful free GIS software such as QGIS due to the lack of internet connectivity.

5.7.3 GIS PEDAGOGICAL KNOWLEDGE OF TEACHERS

Pedagogical content knowledge is defined as the exclusive form of knowledge needed by the teacher to teach the subject, it represents what the teacher knows about the subject and being able to teach the content using appropriate methods (Shulman, 1986). It denotes the "merging of content and pedagogy into an understanding of how specific topics, problems, or issues are organized, represented, and adapted to diverse learning styles and abilities of learners, and presented for instruction." Shulman's (1987, p. 8). It is important to recognize the distinction between general content knowledge (CK) about a subject and pedagogical content knowledge (PCK) specific to teaching that subject. According to Baumert et al. (2010, p. 136), there is a substantial "consensus in the teacher education literature that a strong knowledge of the subject taught is a core component of teacher competence." If a teacher has a deeper subject knowledge, he/she is well placed to teach and explain the concepts in that subject. It is from this perspective, that GIS knowledge and skills are important for a geography teacher in facilitating teaching and diffusion of GIS technology in high schools. It is claimed that experienced teachers have skills that they have accrued over the years to deal with learners and pedagogical problems (Darling-Hammond et al. 2020). Mr Ngubane who was observed teaching: Spatial and Spectral Resolution to Grade 11, highlighted his limited knowledge in GIS content as one of the inhibiting factors of GIS diffusion. His lack of GIS content knowledge affected his attitude towards teaching GIS as a topic. This was shown in the approaches which he used during the lesson. He did not make any effort to make the GIS concepts interesting to the leaners. Mr Ngubane demonstrated a negative attitude towards GIS during the interview before the lesson observation. During the lesson, he used a textbook and instructed the learners to read it, summarise the notes in the textbook and that constituted his lesson on spatial and spectral resolution. There is a growing body of work on teachers' content knowledge and how these impacts on learner learning (Burroughs, et al., 2019) which implies that Mr Ngubane's limited content knowledge will have adverse repercussions for his learners.

However, contrary to this argument, the findings from this research found that experienced teachers in Geography were lacking in the subject knowledge of GIS and less experienced teachers apparently were seen to be doing extremely well. This was attributed to many factors which will be briefly discussed on the following section.

5.7.4 GIS IS NEW

GIS was introduced in high school education in many countries not more than 15 years ago (Forster & Mutsindashyaka, 2008; Akinyemi, 2015; Mzuza & van der Westhuizen, 2019; Mkhongi & Musakwa, 2020). For instance, GIS was introduced into the high school Geography curriculum in South Africa in 2006, in USA in 2005, in Turkey in 2005, in Rwanda in 2008, to name a few countries. GIS being a new addition to the curriculum with seasoned Geography teachers not having exposure to acquiring GIS content knowledge poses a big challenge to many teachers. GIS content knowledge (CK) is lacking in many educators (Mzuza & van der Westhuizen, 2019; Mkhongi & Musakwa, 2020). Results from this research showed that many teachers were not trained in GIS, were struggling to teach it to the learners. Teachers who had GIS content knowledge (CK) and pedagogical knowledge (PCK) were better off in explaining and teaching GIS. Mr Robson and Mr Douglas who had less than 5 years teaching experience who specialised in Geography, Mathematics and Technology subjects exhibited substantial GIS content knowledge (CK) and pedagogical content knowledge (PCK). This was evident in the way the teachers explained the content to the learners and the pedagogical approaches they chose to teach the specific content. In most cases teachers teach best from what they know and exposed to. If the teachers lack the content knowledge of the subject they teach, it becomes difficult for them to explain the content to the learners. The teachers observed in this research should that the teachers lacked the content knowledge in GIS and as such they experienced some challenges in explaining some of the topics they were teaching. It is extremely difficult for the teachers to teach in the subject where they lack content knowledge. Knowledge in the subject content is important (Shulman, 1996). In this research GIS content knowledge was important, for without the content knowledge of GIS, and choosing the most appropriate pedagogy, teaching the content proves to be challenging for teachers. This finding was further attested to by Melo-Nino et al. (2020) who researched PCK in Physics. They suggested that subject knowledge for the teacher is very important. Without solid knowledge of the subject matter, the teachers cannot employ a variety of pedagogical approaches when teaching the subject. This underscores the argument that, for teachers to be effective, they need to have the requisite pedagogical skills, know the content of the subject they are teaching, and possess the skills to deliver the knowledge in a way that can be best understood by the learners given their specific context. However, this is insufficient for GIS diffusion in the class because there are several constraints experienced by teachers such as a lack of physical and instructional resources and infrastructure to support GIS which limits its diffusion (see Figure 5.1).

5.7.5 TEACHERS' ATTITUDES TOWARDS GIS INCLUSION IN GEOGRAPHY IN THE FET PHASE

Teachers' attitudes towards GIS technology determines whether the technology will be integrated successfully in classrooms (Hew & Brush, 2007; Keengwe & Onchwari, 2008; Reid, 2017; Fedorenko, 2018; Demirbağ & Kılınç, 2018). Teachers who quickly embrace and assimilate new technology and alter their practices, according to Dexter et al., (1999), are more likely to integrate computer applications into their instruction. In the questionnaire and during the pre- and post-interviews of this research, teachers were presented with statements that determined their attitudes to GIS. The attitudes of the teachers were also noted during the classroom observations. The pre- and post-interview questions originated from the preliminary findings of the questionnaire. Teachers were given ten statements about GIS and asked to rate their level of agreement on a five-point Likert scale (adapted from Demirci & Karaburun, 2009) in an endeavour to understand whether the teachers' attitudes towards GIS contributed to their use and integration of GIS in geography lessons. To get a deep understanding of the attitudes of the teachers towards GIS technology, these statements were measured against age, gender and type of schools.

The results of the interviews, lesson observations and questionnaires conducted in this research show that teachers had different attitudes about the introduction of GIS in the geography curriculum in the FET phase. The majority, seven of 10 teachers interviewed, indicated positive attitudes, and three out of 10 had negative attitudes about the inclusion of GIS in geography at the FET phase. These findings were also confirmed by the data generated by the questionnaires used in this research. Research by Demirci and Karaburun, (2009) at Turkish secondary schools revealed that teachers' attitudes towards GIS were positive. According to Demirci and Karaburun (2009), most Turkish teachers agree that GIS is a valuable tool for teaching and learning geography and that it should be used in geography classes. Demirci and Karaburun (2009) further went on to say that having a positive mindset is a vital first step toward GIS diffusion and implementation in geography lessons. Also, research closer to South Africa, in Rwanda, on an assessment of teachers' attitudes towards GIS showed that teachers were positive about GIS (Akinyemi, 2015). Therefore, teachers' attitudes towards the integration and diffusion of GIS technology are very important (Fedorenko, 2018; Demirbağ & Kılınç, 2018). Educators' attitudes, beliefs and skills are a major enabling factor for the adoption of technology such as GIS (Bullock, 2004; Cubukcuoglu, 2013). Since beliefs and skills are intrinsic to teachers, these will be possibly more effective factors in enabling the use of GIS in teaching and learning geography than other extrinsic factors such as the infrastructural factors.

5.7.6 PRE- SERVICE AND CONTINUOUS PROFESSIONAL DEVELOPMENT IN GIS

Davis, Bagozzi and Warshaw (1989) state that experience alone is not enough; it must be accompanied by expertise and effectiveness in the subject content. A teacher can be experienced in doing "wrong things", and this can be detrimental to teaching and learning in the classroom, because such teachers might find it very difficult to change and to adopt modern ways of teaching, such as in adopting and integrating GIS in teaching geography. Morgan and Lambert (2005) argue that teachers have to consistently engage with their subject content to ensure that their lessons are grounded in the subject they teach. If this is not done, there is danger that content, in this case GIS topics, will not be able to be taught properly in the class. This view is confirmed in the findings of this current research. Mr Ngubane, Mr van Wyk and Ms Fatima who had over 25 years of teaching experience, admitted that they were not comfortable teaching the GIS section of the geography curriculum. When the effectiveness and expertise of the geography teachers who showed some difficulties in GIS topics were interrogated further, the teachers attested that they did not understand the GIS concepts they were teaching. The teachers did not have the necessary content knowledge of the GIS concepts stated in the CAPS to be able to teach it.

Research also confirms that teachers who have knowledge of instructional strategies are most likely to apply different pedagogical approaches to presenting and explaining subject matter to learners (Shulman, 1986; Melo, et al., 2020). Teachers who lack deep content knowledge are expected to be less effective and teachers with knowledge of the subject matter tend to be effective and can use a variety of ways to explain the content to learners. These teachers are confident, and they try different pedagogical approaches and can be innovative in their approach. Studies from the United States (Hill et al., 2005; Clotfelter et al., 2006; Chingos & Peterson 2011; Shuls & Trivitt, 20015; Muhaimin et al.,2019) have discovered some evidence that stronger math instructor cognitive skills are linked to higher learner scores. This was also confirmed in some of the lesson observations made in this research. Young and novice teachers I observed at private and former Model C schools were more innovative in their approach to teaching GIS topics. This innovativeness was the result of the teachers' reporting that they had done some GIS modules for their degree when they were at university, hence, they found the teaching of GIS in high school easy. On the contrary, older teachers who did not have GIS as part of their training at colleges and universities struggled to teach the GIS topics, because they had no exposure to GIS previously and this hampered their teaching of the topics in GIS. As attested to earlier, the literature is divided on the relationship between teachers' knowledge and learners' performance. Studies in Germany (Baumert et al., 2010; Metzler & Woessman, 2012), as well as a comparative study by Hanushek et al.,2018 using data from the Programme for the International Assessment of Adult Competencies (PIAAC), found positive relationships between teachers' content knowledge and learner outcomes. These findings are not universal, other studies from United States of America (Blazar 2015; Garet et al., 2016) found no statistically significant link between teachers' content expertise and learner learning.

5.7.7 GIS CURRICULUM TIME AND ASSESSMENT

GIS questions are tested in question 4 in paper 2 of matric examination. GIS questions constitute 15 marks of the 75-mark paper 2 geography examination in matric. Many teachers were of the view that GIS topics had a small assessment weighting, which translates to just 5% of the total marks in the geography examination. The low weighting in GIS section aligns with teachers not prioritising its teaching. The teachers were resorting to fostering learner memorisation of the answers when the learners are about to write the final examination. This small weighting negatively affects the diffusion and integration of GIS in schools in Frances Baard District. Teachers do not put much effort into teaching GIS topics because they do not contribute many marks in the examination. Also, GIS is not allocated much time hence it will be difficult for teachers to dedicate time to the practical aspects of teaching it because they will be unable to complete the long geography syllabus. Due to all these inhibiting factors such as teachers' experience, the majority of teachers in this research resorted to 'teaching about GIS' rather than 'teaching through GIS'. As a result, 'perfunctory GIS teaching' was evident in the mechanical, minimal effort, unenthusiastic manner of teaching. Many teachers were 'curriculum cramming' - they hurtled through the GIS section of the CAPS and failed to integrate it with other Geography topics in the curriculum due to the curriculum and assessment demands for GIS.

5.8 ENABLING FACTORS IN GIS DIFFUSION IN FRANCES BAARD

For GIS technology to diffuse at a faster pace in Frances Baard District schools, it is important to understand the value of certain factors, how they intercept and influence each other and thus their role in GIS diffusion in this study area. The research findings indicate that the following factors need to be addressed by the teachers, school managing authorities and the department of education in the study area for improved diffusion (Figure 5.2 and Figure 5.3). The factors that influence the diffusion of GIS can be grouped into the following systems: macrosystem, exosystem, mesosystem microsystem and chronosystem (Guy-Evans, 2020).

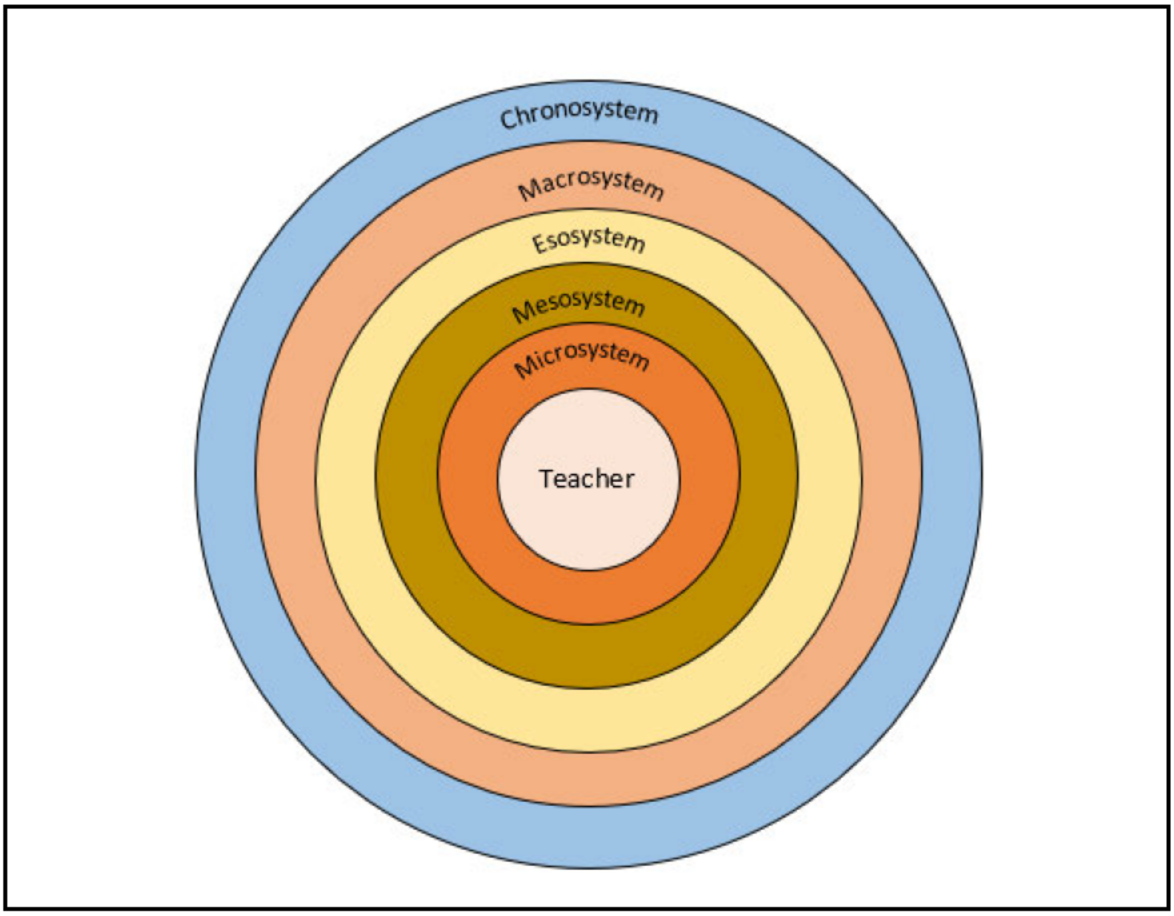


Figure 5.2: Enabling factors for GIS diffusion in high schools in the Frances Baard

Drawing from Bronfenbrenner's theory (Guy-Evans, 2020), using the six different levels that influence the diffusion of GIS technology in schools, this phenomenon of ecological systems can be better understood. Level 1 is the individual teacher. The teacher interfaces with learners in the classroom and thus plays a very important role in growing learners' knowledge of the technology in the class. In the model (Figure 5.2), the teacher is found at the centre and as such he/she influences GIS diffusion in the class by having a positive attitude, that is encouraging, having the prerequisite knowledge and teaching the content by breaking the content into small manageable learning chunks (correct teaching methods for new content) that can be easily understood and grasped by the learners. For the teacher to influence learners and help to transmit the technology he/she must have access to relevant content knowledge (CK) and be trained in sound technological and pedagogical content knowledge (TPCK). As indicated in Figure 5.3, the teacher should be equipped with all these factors so that he/she is able to function well in the classroom in teaching GIS effectively.

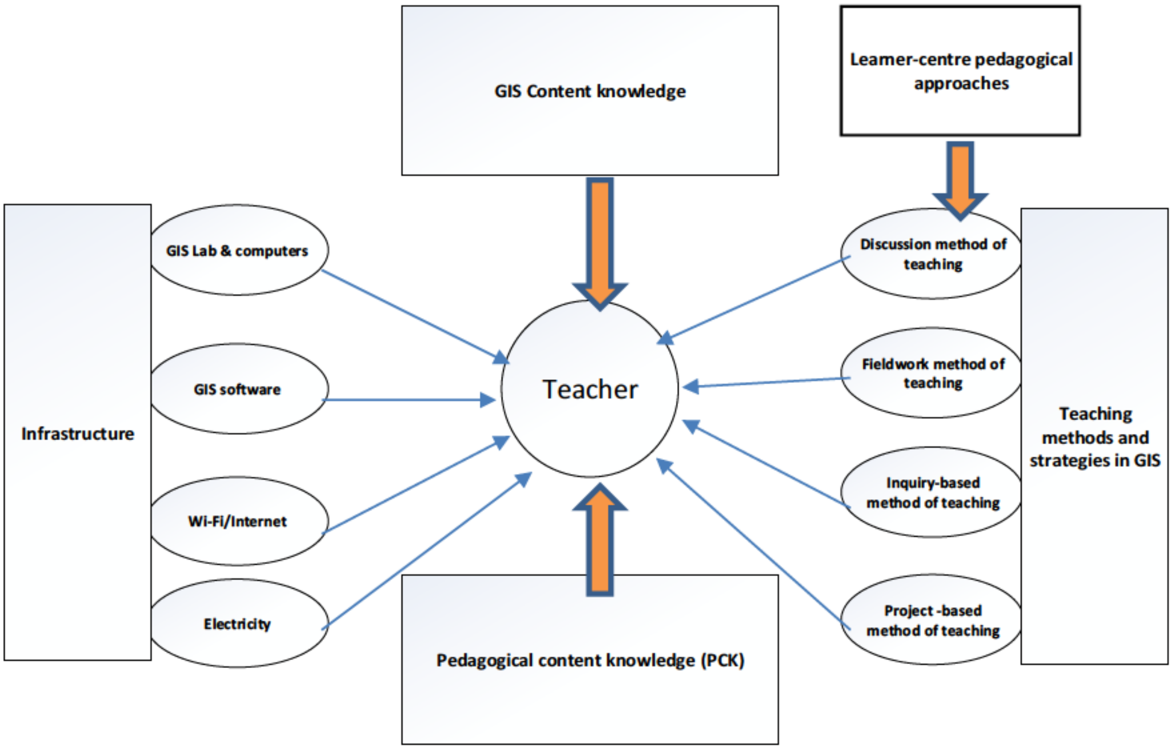


Figure 5.3: Enabling factors for GIS diffusion in high schools in the Frances Baard

As can be seen on Figure 5.3 some of the enabling factors for GIS diffusion are beyond the control of the teacher but facilitates the diffusion of GIS in the classroom. According to Guy-Evans, (2020), level 2, includes the broader wider system and we can interpret this as the school management system, and it represents a sphere of support provided through the combined activities of the district education authorities. In this model (Figure 5.3) the teacher cannot operate in a silo but is affected by microsystem (peers in the school) mesosystem which is the school, the exosystem which represents the community and cluster of schools and even the district offices of the Department of Basic Education (DBE). These factors negatively affect the individual teacher in the sense that they are damaging as the teacher does not have any influence in making decisions at these levels (Guy-Evans, (2020) save for perhaps motivating at the mesolevel of the school or exosystem (the DBE) for motivating for either hardware (e.g., computers) or for in-service training in GIS respectively. The teacher has limited power to build the GIS laboratory and to provide electricity, but the teacher can raise funds to purchase or attract industry funding for computers and GIS software. The teacher does depend on the relevant authorities to put infrastructure into place which can promote GIS diffusion in schools. The level of the macrosystem involves a cultural or political context. In this research, this can be the province in which the school is found and where the individual teachers are located, and which have their own budget and policies related to the funding and functioning of schools (depending on the quintiles) based on their unique challenges. This can also refer to the education policies for example, teachers do not determine the weighting of the GIS section. This is determined by Department of Education in the country by those people who formulate the curriculum. The last level, the chronosystem according to Herselman, et al., (2018) are the environmental events, historical events, and major life changing events like death in the family or an outbreak of something unforeseen like wars or pandemics that can affect how individual teachers can teach GIS technology. For schools, these are the historical disadvantages that are still prevalent in Black schools due to apartheid. In this model (Figure 5.2 and Figure 5.3), this study revealed that the diffusion of GIS in schools in the Frances Baard District is not only hampered by the factors discussed by TAM and Rogers' theories, but it is influenced by many factors within the school environment and also by aspects across the entire ecological system of education (Geldenhuys & Wevers, 2013). Chronosystem factors as stated by Herselman, et al., (2018) also refers to the historical privileges that white schools have in their location and infrastructure and facilities that prevail to the current day whilst many Black schools remain disadvantaged from the days of apartheid unable to catch up in democratic SA. These disparities in terms of location infrastructure and school resources continue to stifle GIS diffusion.

5.8.1 EMPOWERING TEACHING METHODS OF GIS

The teaching approaches are another enabling factor which help in diffusing GIS technology. The teachers who showed positive attitudes towards GIS had different approaches to teaching. A teacher who is innovative, uses what resource is available in the classroom and exploits it for successful teaching and ensuring that the learners understand the topic. A teacher who is creative uses modern technology which is available to teach GIS. The pedagogical approach (learner-centred) that was employed by Mr Van Wyk when he was conducting his lesson was informed by his constructive attitude toward GIS. When he was teaching the concept of 'Remote Sensing' and Resolution to Grade 12, he asked the learners to use their cell phones to take a picture and then asked them to zoom the pictures in and out and to note what was happening to the image. I believe this was a constructive attitude, which provided an authentic education, despite the shortage of physical, resources in the classroom.

The teacher was creative and made use of the resources that were available to the learners although the school did not have the necessary resources. This finding was confirmed in the literature by Buabeng-Andoh (2012) on factors influencing teachers' adoption and integration of information and communication technology into teaching in Ghana, who discovered that successful implementation of educational technology in schools is heavily dependent on teachers' support and attitudes. As a result, if teachers perceive technology as not meeting their needs or the needs of their learners, they are unlikely to incorporate technology into their teaching and learning, and thus diffusion of the technology will not occur. In Mr Van Wyk's case, his attitude to GIS was positive and he acknowledged its value thus he found a creative and accessible way to teach GIS without the school's resources, by drawing on the learners' resources and hence diffusion of the technology was evident.

As a result, school technology integration is a complex phenomenon that demands a knowledge of teachers' motives, attitudes, and beliefs about learning and technology integration (Keengwe & Onchwari, 2008), as well as the effective use of available resources. Technology integration and dissemination are more easily performed if teachers appreciate a sort of technology and believe it will help their courses (Rogers, 2003; Hew & Brush, 2007; Hanushek, et al., 2018).

5.8.2 TEACHERS' VIEWS ON GIS

The main thrust of this section is to discuss teachers' views and their perceptions about GIS in the geography curriculum in the Northern Cape province of South Africa. Teachers' views refer to the teachers' articulations, about what they think about GIS in general. It does include their perceptions which "relates to the process of making sense of the surrounding objects and events upon organizing and interpreting available sensory data" (Şanli, Sezer & Pinar, 2016, p.237). In this research, the views of teachers were sought in trying to understand their thinking about GIS and what they have available regarding GIS technology and teaching. One of the critical questions was on the views of the teachers but during data generation, the participants harboured certain perceptions which were revealed hence I found it prudent to use both concepts in the findings. As such, views and perceptions were extracted from the data provided by teachers of geography at public schools and private schools. This section links the findings of this research with the literature about the views and perceptions of teachers about GIS inclusion in the geography curriculum and how these influences the diffusion of GIS in these high schools. Overall, the teachers perceive GIS to be difficult to teach because it was not part of the preservice training though they viewed it as a valuable technology that promotes the building of critical thinking skills in learners.

The study's empirical findings reveal that the availability of physical material resources has a strong bearing on the perceptions of teachers towards their use of GIS in the classroom. At the schools where the teachers had access to a computer laboratory and the geography teachers were allowed to present some geography lessons in the laboratory, the teachers' views were much more positive than that of teachers at schools which were lacking in a computer laboratory. The teachers who teach in former Model C schools, which can afford to equip their computer laboratories with the necessary computers and GIS software, used exciting teaching methods, such as giving their learners projects and GIS assignments to do with QGIS. This discovery in the findings resonates with the literature. A research study by Ates (2013) in Turkish high schools on the perceptions of geography teachers towards GIS found that teachers who had computer laboratories, GIS software, projectors, and GIS data available at their schools had a positive orientation to GIS and they viewed GIS as promoting critical thinking in learners and helping the learners to develop an inquisitive mind. This notion was confirmed by the data I gathered in the survey which showed that the majority of teachers were positive and aware of the advantages that GIS can have on their learners. About 53.3% of the teachers stated that they were willing to attend in-service training on GIS because their perception was that GIS workshops would be beneficial to their teaching of the GIS topics in the CAPS. By contrast, some teachers viewed GIS as difficult to learn and to teach because they perceived GIS without resources such as a computer and GIS software as being an impossible hurdle to their teaching. This is further discussed in the following sections.

5.8.3 USEFULNESS OF GIS IN THE GEOGRAPHY CLASS

The attitudes of teachers towards any subject or concepts taught determines the effort and innovation a teacher puts into the lesson (Ababio, 2013; Omolara, 2015). The absence of a positive attitude towards an innovation tends to derail the adoption of innovation in an organisation or institution. Most (70%) of the teachers I observed teaching GIS were not innovative enough to use the resources which were readily available in their classrooms. Mr Ngubane who was observed teaching Spatial and Spectral Resolution in grade 11 could have used the cell phone the learners have in the class to demonstrate and aid in his explanation. Instead, Mr Ngubane resorted to reading from the textbook and writing notes on the chalkboard. Mr Ngubane portrayed a negative attitude to GIS and in a post lesson observation interview, he suggested that he could not see the use and importance of GIS in general. This observation resonates well with TAM theory and the concept of Perceived usefulness (PU), (Davis, Bagozzi & Warshaw, 1989), which states that if a person thinks that the innovation is not useful, the chances are that the person will not make an effort to adopt the technology. Mr Ngubane did not make effort to use the readily available resource because he could not see the usefulness of GIS. Ms Fatima who was observed teaching *Application of GIS* to grade 11 class also portrayed the same resentment of the GIS technology. During the lesson, Ms Fatima was not using authentic and day to day application of GIS. She could have used the smart phone to show learners how GPS location helps to find the location of places as an application of GIS. Although these factors are known to affect the technology diffusion and adoption, there other factors which were identified in this research (see Figure 5.2 and Figure 3.2). All these factors in Figure 5.3 influence the attitude and the behaviour of an individual or organisation whether to adopt or not to adopt a technology/innovation. The acceptance of an innovation in a society, organisation or, in the case of this study, in the classroom, depends on external variables, such as lack of GIS knowledge, lack of GIS laboratories, Lack of GIS software, lack of internet connectivity, lack of electricity connectivity etc (see Figure 5.2 and Figure 5.3). These factors and many other factors hinder the diffusion of GIS in the schools in Frances Baard. All the schools visited in the study area did not have GIS laboratories and some schools especially the rural schools do not have a geography subject classroom. All the teachers teaching different subjects have to come to the same classroom to deliver the different lessons. Perceived usefulness and perceived ease of use and the support the teacher gets from the school, provincial department of education, local stakeholders such as the universities and the municipalities are all valuable factors in the diffusion of GIS. If the teachers receive the necessary support, his/her perception might change. In this study, most of the teachers perceived GIS as difficult to teach and to use in the geography lessons. This perception shaped the teachers' attitudes towards using GIS. Although the majority of the teachers who participated in this research indicated a positive attitude towards the inclusion of GIS in the geography curriculum, their actions (behaviours) were not consistent with their behaviour, especially the 10 teachers who were interviewed and who had their lessons observed. This suggests that, even though the teachers had strong feelings about the value of GIS for the learners, their attitudes were not yet aligned with the action they took in the classroom. Very few teachers were using creative methods when teaching GIS topics. For instance, Mr Ngubane who was observed teaching Spatial and Spectral Resolution in Grade 11 did not try to utilise what was available in the classroom. The teacher read from the textbook and wrote the notes on the chalkboard. The teacher did not try to show the learners what was an attribute table and how it is generated in GIS processes. Also, Ms Mable who was observed teaching Querying and Statistics analysis in GIS did not allow learners to ask questions during the lesson. A lack of confidence by a teacher when explaining concepts and a lack of effort to impart GIS knowledge is a disabling factor for GIS diffusion by teachers. Most of the learners were not following the lesson and there would have been minimal GIS learning taking place during these lessons. Although there is free GIS software (QGIS) available that teachers can download from the internet, some teachers were not exercising any effort to download it and improve their GIS lessons. Their lack of GIS knowledge was translating to a lack of teaching effort in GIS lessons. This could also be due to the teachers themselves perceiving GIS technology as not a useful tool in teaching geography although they were articulating a different view to the researcher.

5.8.4 EASE- OF- USE OF GIS

Most of the teachers in this research perceived GIS as a difficult technology to use in the classroom. They view GIS as unfriendly technology which requires a lot of time to learn. This is compounded by their experiences of a lack of physical resources such as GIS laboratories, computers, GIS software and lack of training. Although there is a free version of GIS (Quantum GIS) which teachers can download, the majority of the teachers stated that even if they can download it, they find it difficult to use it because they were not adequately trained. This finding is supported by the literature reviewed in this research. Mkhongi and Musakwa's (2020) research on perspectives of GIS education in high schools in uMgungundlovu District in KwaZulu-Natal, South Africa, and Mzuza and van der Westhuizen's (2019) research on the state of GIS teaching in secondary schools in the Southern African region support this claim. This problem of perceiving GIS technology as difficult to use in the geography classroom is further compounded by teachers' lack of adequate training in GIS and a lack of resources which have been widely reported in South Africa. Globally, research by Siegmund et al., (2007) in Germany on GIS in the classroom –challenges and chances for geography teachers found that large numbers of geography teachers have not yet come in contact with GIS. These challenges have a negative impact on the spread of GIS technology in the classroom. If the teachers who are supposed to introduce the technology to the learners are lacking in confidence with the technology, it will be very difficult for the learners to learn it, enjoy it and see value in it.

Overall, the rationale for incorporating GIS into the geography curriculum appears to have been completely accepted by the participants (CAPS). The majority of participants (80%) saw GIS technology as a viable educational tool with the potential to transform learners into critical thinkers and real-life problem solvers. The findings indicate that the teachers have already passed through the knowledge and persuasion stages of Diffusion of Innovation (Rogers, 1995) and are now at the decision stage. There are inequalities between the private schools and township public schools and former Model C (now part of public school system) schools. Some schools especially former Model C schools are well equipped when compared to township and rural schools. The teachers in these different categories of schools are found to be at different stages of Rogers theory of DOI and this has a bearing on their perception of the GIS. Majority of the teachers I interviewed from the township and rural schools perceived

GIS as a difficult technology to use while those from well-resourced schools see GIS as a fairly easy technology to use. Many theorists contend that attitudes can often predict future decision-making behaviour (Fishbein & Ajzen, 1975; Hartman, Townsend & Jackson, 2019).The teachers' positive attitudes towards GIS in geography education is a good sign that the teachers are ready and expected to use GIS in their classrooms once computers, GIS software programs and internet are made available to them. The findings also show that the teachers are willing to learn more about GIS, a commitment to improve their professional knowledge and competences. This was evidenced by the majority of teachers who yearned for more training in teaching GIS.

In this study's findings there was a significant correlation between the geography teachers' views towards GIS, their gender and age. Young teachers aged 26-29 and 30-39 years had more positive views on GIS than teachers aged between 40-49 and older than 50 years. These findings resonate with the literature (Aydin & Kaya, 2010). Members of the age group 26-40 years can be considered as "digital natives". Digital natives are the people born in the digital era, that is, Generation X and younger (Zur and Zur, 2011, p.1). Zur & Zur further stated that this group is also referred to as the "iGeneration" or is described as having been born with "digital DNA." (Zur & Zur, 2011, p.1). On the contrary, the term "digital immigrant" refers to the people who were born and grew up in pre-computer time, before 1964 (Zur & Zur, 2011) and those forced to become digital, like the older teachers where GIS is included in the curriculum are best called 'digital refugees' (Khoza, 2018). Prensky (2001) popularized and elaborated on the words "digital immigrants" and "digital natives," and Harding & Whitehead (2013), among others, evaluated their validity and utility. "Digital natives speak the language of computers and the culture of the web into which they were born" (Zur & Zur, 2011, p.1). On the other hand, digital immigrants and digital refugees do not deal with technology in a simple and natural way as those who grew up in the era of computers. To link this with the findings of this research, it was found that the age group between 26-29 and 30-39 years were more willing to accept and use new technology (including GIS) than older people. Although a correlation between age and GIS knowledge of teachers did not emerge strongly from the questionnaire data collected, GIS as a technology tends to be more familiar to younger people. The data provided by high school teachers in this study showed some variance regarding their views and attitudes on GIS. The majority of teachers who were over 50 years exhibited some negativity in their views and attitudes towards the inclusion of GIS in geography.

5.9 PEDAGOGICAL APPROACHES FOR CLASSROOM CONTROL

Effective teachers plan their work carefully in advance and use appropriate pedagogy. The pedagogical approaches used by the 10 teachers who were observed and 50 teachers who participated in the survey represent a variety of approaches, which range from teacher-centred to learner-centred approaches (Omoro & Nato, 2014). The findings from the interviews, questionnaire survey and lesson observations were that many teachers used teacher-centred pedagogical approaches and different teaching methods. This was confirmed by the literature that was reviewed, which reports that teachers do not adhere to one pedagogical approach when teaching (Hardman, Abd-Kadir & Smith, 2008; Du Plooy, 2015). The size of the class, as well as the availability of physical teaching resources and instructional materials such as textbooks, often determined the teachers' pedagogical approaches. In most schools observed there was shortage of textbooks and learners were sharing textbooks and this negatively affected the pedagogical approaches of the teachers.

Most teachers who were observed used the direct instructional approach. In this case, teachers used teaching methods such as explanation, questioning, the lecture method, and demonstration to teach GIS. These methods were used for several reasons. The lecture was used mainly when the teacher wanted to cover a great deal of content (Kagoda 2010; Ondigi, 2012; Kagoda & Sentongo, 2015). In addition, most of the teachers used the lecture method because they believed that it gave them control over the learners, which are difficult to control in most of the times and it consumed less time over what they wanted to teach them. These findings are in agreement with Killen’s (2012) observation that teachers use direct instruction, such as the lecture strategy because it allows them to have complete control over what, when, and how learners learn in a lesson.

However, the lecture approach has limitations. It does not give learners the opportunity to engage with the teacher and the content to co-construct knowledge. Co-construction of knowledge is that knowledge learners get when they learn from each other when they discuss among themselves and when they engage further with the teachers. (Ahn & Class, 2011; Van Schaik, Volman, Admiraal & Schenke, 2019). Co-construction of knowledge can be achieved when learners help each other in groups to solve issues. It helps them to build relationships among themselves and between the learners and the teachers (Ahn & Class, 2011 p.270). The teacher is regarded as the source of knowledge and his/her duty is to transmit knowledge from him/herself to the learners. The learners are supposed to receive this knowledge passively without being actively involved (Akengin, 2008). Most of the teachers pointed out that they use direct instruction as a method because they were overwhelmed by the length of the geography syllabus which compelled teachers to use teacher-centred pedagogical approaches, such as the lecture, explanation, and questioning methods, to save time and to finish the curriculum in the time available.

The teachers also used the lecture, explanation and questioning teaching methods when introducing new topics and concepts in GIS. This notion that directs instruction is mostly used when learners are being introduced to a new area of study (Killen, 2012; Shanmugavelu, et al., 2020). They argue that it is appropriate for developing learners' basic knowledge and skills should be reinforced through direct instruction before they are given a more active role in knowledge-seeking activities such as problem-solving or experimentation (Killen, 2012; Shanmugavelu, et al., 2020). There is a need, therefore, for the teachers to lay the foundations of GIS knowledge, for example, by showing and demonstrating to the learners how buffering is done in GIS or how digitising is done, first and foremost, before asking learners to do it on their own. Because GIS is a practical topic, teachers need to create the building blocks of ideas and skills on how certain operations are done, first, by giving comprehensive explanations and some demonstrations before the learners are allowed to experiment on their own. This is not to say that constructivist approaches to teaching are incompatible with direct instruction. The approach simply underscores that sometimes learners need to be carefully guided and this case direct guidance is necessary as it helps the learners to pay attention to important aspects in the lesson (Killen, 2012; Lombardi, 2019; Shanmugavelu, et al., 2020). Most of the teachers I observed teaching GIS were not applying these skills and approaches. The teachers were using the lecture method when delivering the lessons. When I asked them why they chose the teaching methods they were applying during the lessons they stated several reasons. Some of the reasons are summarised on Table 4.27.

5.10 TRADITIONAL APPROACHES TO TEACH A NEW TECHNOLOGY

The pedagogical approaches used by most of the teachers in this research are traditional teacher centred approaches. Interactive methods were used by a few teachers at former Model C or quintile 1 and 2 schools and private schools. This was expected, because few lecturers at training colleges and universities use interactive methods that are mainly learner centred (Kagoda & Najuma, 2013). Teachers usually use teaching methods or pedagogical approaches that they themselves experienced while they were being trained (Kagoda, 2010; Kagoda & Najuma, 2013). I observed that only a few teaching aids were present and used properly in the lessons. Most teachers often used the textbook and the atlas maps, of which, in some instances, there were not enough copies for all the learners. This over dependence on textbooks was articulated by Manik and Malahlela (2018) in a study on Pedagogy and Geography CAPS textbooks. Due to these shortages and the lack of internet connection at most schools, GIS is taught at high levels of abstraction, and this makes the teaching and understanding of GIS challenging and limits its diffusion in schools.

The teaching environment was also noted to be one of the hindering factors in as far as the appropriate pedagogy for GIS is concerned. Very few of the schools that I visited had proper learning environments for GIS teaching. Only former Model C schools and private schools had adequate learning environments. The learning environment includes computers with GIS software, proper desks for the learners, proper teaching aids, such as maps, atlas books, a variety of geography textbooks, chalkboards, white and smart boards, data projectors, globe models, and topographic maps. These geography teaching environments were missing in most rural and township schools where I visited, where the environment was characterised by overcrowded classrooms, broken desks, a shortage of textbooks, lack of relevant teaching aids in the classroom, and had no map atlas, topographic maps, internet connection, data projector and global models and no computers with GIS software. In some instances, the physical and cultural environments around the schools were not fully utilised to the benefit of GIS teaching in the schools. GIS teaching was more oriented towards 'curriculum cramming' comprising rote learning and memorisation of answers, and less towards teaching to help learners understand the concepts. All the factors highlighted above form part of maladaptative signature pedagogies of geography (common to the discipline) classes in this context. Without an enabling teaching environment, the teaching and learning of GIS is unlikely to succeed. This observation was also made in Turkey by Akengin (2008). Some learners in the classes where I carried out lesson observations were noisy and rowdy, they did not participate, were less prepared for the lessons and lacked respect for the teachers. This affects the teaching and learning of GIS given that the general pedagogical skills of teachers were put to the test by large class sizes with poorly disciplined learners.

Most of the teachers struggled with teaching the GIS content, as a result, their choice of teaching methods was compromised. If teachers do not know the content they have to teach, the pedagogical approaches and teaching methods/teaching strategies they will employ in the lesson will be affected negatively (Marquard & Sørensen, 2011). The choice of pedagogical approach and teaching method, therefore, depends very much on the overall goal, choice of content, the situation (context of the school), the subject and the learners' conditions (Marquard & Sørensen, 2011). The findings of this research confirm the literature (in Chapter 2).

5.11 RATIONALISING THE PEDAGOGICAL APPROACHES TO TEACH GIS

This section discusses some of the reasons why the teachers used certain pedagogical approaches/teaching methods and teaching strategies when teaching GIS. The findings from the interviews and surveys show that teachers had different reasons for preferring to use certain pedagogical approaches. Among the reasons were a lack of knowledge, the nature of the content matter, nature of the learners and availability of the physical teaching and learning materials, crowded classrooms, and the way they were trained at colleges and universities.

5.12 LACK OF CONTENT AND PEDAGOGICAL KNOWLEDGE OF THE SUBJECT

As highlighted on the previous section, most teachers interviewed and surveyed were of the view that they do not have sufficient knowledge about GIS content, and find it difficult to teach GIS topics which they do not understand. As stated by Marquard and Sørensen (2011); Mzuza and van der Westhuizen (2019); Mkhongi and Musakwa (2020) a subject's content knowledge plays a very important role in choosing effective pedagogical approaches for teaching in any subject content. Teachers cannot integrate pedagogy into the content knowledge if they do not understand the content they are teaching (Kiamba, Mutua & Mulwa, 2018), just as they cannot plan and organise it at the level of the grades they are teaching. Kiamba, Mutua, and Mulwa (2018) discovered that a classroom teacher's subject matter knowledge is significant and extremely critical in impacting pupils' academic progress in Kiswahili language in Kenyan public secondary schools. Teachers' intellectual subject knowledge determines their ability to engage learners' minds and hearts in the learning process (Kiamba, Mutua & Mulwa, 2018). Subject matter study is supposed to provide teachers a better understanding of the content they'll be teaching. If teachers understand and have a deep knowledge of the content they teach, then they are better placed to break that content up into small elements that the learners can understand (Kiamba, Mutua & Mulwa, 2018; Shulman,1987). PCK, as explained by Shulman (1987), gives a grasp of how certain aspects of the subject matter are organized, adopted, and portrayed for instruction by combining content and pedagogy. PCK is an "amalgam" of pedagogical and content knowledge. In this case, PCK includes an understanding of what makes particular GIS topics simple or difficult to learn. Understanding learners' needs, ages, and backgrounds is critical to how learners learn (Shulman, 1986, p. 9).

Also, a lack of knowledge of suitable pedagogical approaches to teach GIS content presented a big challenge to most teachers. The geography teachers stated that they had not been exposed to different pedagogical approaches when they were being trained at colleges and universities and some mentioned that they did not do GIS modules when they were doing their training. For example, most lecturers at colleges and universities used the lecture method, and therefore, when the teachers graduated from universities and colleges, they mimicked the same approaches, because that is what they were exposed to, and know about. The lecturers at colleges and universities should role model different pedagogical approaches to student teachers, as this will equip teachers with a variety of teaching methods and teaching strategies. However, even at universities, the lecture method has survived to teach extremely large classes which makes it difficult to employ other teaching methods (Schmidt et al., 2015). This is also worsened by some set up in many universities where some of the content subjects are taught in other schools rather than in the school of education.

5.13 A LACK OF PHYSICAL TEACHING AND LEARNING MATERIALS

The findings of the research reveal that most the high schools, especially in rural areas and townships, lack physical teaching and learning materials. These physical teaching and learning materials include computer laboratories, GIS software, textbooks, topographical maps, map atlases, internet connection and spatial datasets are going to be discussed in the following subsections.

5.13.1 GEOGRAPHY TEXTBOOKS FILLING THE GIS KNOWLEDGE GAP

These physical teaching and learning materials such as textbooks are essential for teaching and learning geography and in particular GIS. Textbooks are important tool for learning, and they are the sole resource supportive of teachers' articulations in certain schools (Manik & Malahlela, 2018). Textbooks can help the teachers to gain the knowledge which they do not have and at the same time can be also used as a teaching resource. Teachers use textbooks for several reasons. They use textbooks to prepare their classroom teaching lessons, for their assessments and for homework. The current study found that teachers who lacked GIS content knowledge were depending on the textbook's information and following the sequence of the textbook to teach their lessons since the textbooks are CAPS compliant. Given that the textbooks are approved by the Department of Basic Education, these textbooks should be written in detail and in a language, which is easy to understand; they should be user friendly. Manik and Malahlela's (2018) study in Eastern Cape and KwaZulu-Natal province revealed that learners lack access to textbooks. According to their findings, textbook shortages have a negative impact on achieving effective teaching and learning and, as a result, learners' performance in geography is very poor especially on mapwork and GIS section of the matric examination. In Manik and Malahlela's research, "teachers also expressed their disappointment at many of the textbooks' quality with respect to inadequate and insufficient geographic content, decontextualised material, extraneous examples and some incorrect information" (Manik & Malahlela, 2018, p.37). They also noted that a lot of learners are excluded from learning and understanding geography because of the difficult language used in these geography textbooks. As a result, the researchers proposed a reimagining of the CAPS textbooks in which stakeholders would address some of the current challenges in using these textbooks.

A lack of textbooks, in the current study on GIS, did affect the choice of pedagogical approaches that teachers selected and used when teaching geography and GIS topics. For instance, if there were not enough textbooks in the class for each child or to share, the teacher will resort to teacher –centred pedagogical approaches such as the lecture method and question and answer approaches. These teaching approaches and techniques do not promote deep learning and critical thinking in geography. The issue of geography textbook shortage was also reported in Swaziland. Research by Kasule (2011) highlights the challenges of textbooks that is being currently experienced in Swaziland. He noted that there are large class sizes which resulted in shortages of textbooks, these findings mirror that of the current study.

5.13.2 LACK OF GIS LABORATORIES AND GIS SOFTWARE

Also, lack of computer lab and computers with GIS software have negative impact since the teacher cannot employ a practical pedagogical method in the lesson. In this research, most of the teachers taught GIS theoretically. They used direct instruction to teach different topics of GIS, because they lacked a GIS laboratory and GIS software. Shortage of these resources affect the diffusion of GIS technology in high schools in South Africa. A lack of physical teaching and learning resources such as GIS laboratories and GIS software is not only unique to South African high schools. Research in Turkey revealed that most of the secondary schools in that country lack these resources, and therefore the diffusion and adoption of GIS is sluggish (Karatepe, 2007; Tuna, 2008; Demirci & Karaburun, 2009).

The findings in this present study, also show that a few teachers, especially in former Model C (now included in the term: public schools) high schools, used different methods such as group work and fieldwork, and demonstration- a hands-on practical approach. These methods are learner-centred and constructivist in nature, and they allow learners to construct their own knowledge and solve problems on their own, and understand their own thinking processes (Kagoda, 2016).

A study carried out by Mzuza and van der Westhuizen (2019) in Southern Africa showed that few countries and few universities in the SADC region teach GIS. They identified a lack of resources and funding as one of the major barriers which stifled the diffusion of this most sort technology in high schools. Some schools I visited had no electricity connectivity and this makes it even more difficult because computers depend on electricity. A lack of electricity connectivity negatively affects the diffusion of GIS technology and this negatively affects the attitudes of teachers towards GIS. Even if a teacher wants to try to integrate GIS in his/her geography lesson, he/she will be limited by the lack of infrastructure: electricity, computers, GIS software and internet connectivity. However, the lack of infrastructure should not lead teachers to capitulate as the study did highlight the creative use of cellphones by some teachers to overcome the challenges.

5.14 CONSEQUENCES OF LIMITED MATERIALS FOR GIS TEACHING

The shortage of teaching and learning (instructional) materials in GIS has repercussions. One of the repercussions is surface learning in GIS. Teachers would not be able to critically teach the content which will be required and as a result, learners will not be able to acquire the skills required. The other salient repercussion which immediately emanated from the lack of textbooks in the lesson I observed during this research was, disciplinary problems. Learners were fighting over the few textbooks which were available, and the teacher spent much teaching time disciplining learners. This finding was also revealed by Manik and Malahlela (2018) in their research on textbooks. They reported that a shortage of textbooks resulted in a wastage of time and those learners were not able to complete their tasks on time. Also, a lack of textbooks and GIS content affects the performance of learners in paper 2 as was seen in the Matric results. A 2020 report on the Matric report in Northern Cape province showed that learners continue to struggle with the questions on Map calculations and GIS in Paper 2 (Department of Education (DoE), (2020). A diagnostic analysis of Matric questions in paper 2 showed that the overall pass rate in the GIS application question was 41% in 2020 (Department of Education (DoE), (2020) which implies that 59% of learners were unable to correctly answer the question. Also, a further diagnostic analysis in GIS section showed that components of GIS was 57%, Site of features and data layers was 26% and vector data was 46% (Department of Education (DoE), (2020). All these statistics indicate serious challenges in GIS teaching in geography. These low pass rates in the GIS questions are flag for teaching and learning GIS technology in high schools.

5.15 CONCLUSION

The study concludes that despite many teachers having a positive attitude towards GIS inclusion in the geography curriculum and agreeing that GIS can promote critical thinking in learners, teachers viewed GIS as a difficult technology to teach. Majority of the teachers in this research who had no GIS preservice exposure, stated that they were not adequately trained (in-service) in teaching GIS. Majority of teachers read the GIS content in the textbooks which they used to teach, and this proved to be ineffective in providing them with the knowledge to teach GIS. They bemoaned that they did not acquire appropriate pedagogical skills to teach GIS for it to be easily understood by their learners. Majority of the teachers used teacher-centred pedagogical approaches when teaching GIS. The teaching methods included questioning, explaining, lecturing and class discussion. Very few teachers used learner-centred pedagogical approaches. The teachers highlighted several reasons why they used certain pedagogical approaches to teach GIS. Some of the reasons which they cited included a lack of teaching and learning materials such as a shortage of textbooks, no GIS laboratories, GIS software, internet connectivity and a lack of electricity in some schools in rural areas. Also, significant was the lack of GIS content knowledge and pedagogical content knowledge by geography teachers.

Older teachers showed a negative attitude towards teaching GIS while relatively young teachers showed a positive attitude and were found to be creative in their teaching approaches. These attitudes correlated to whether the teachers had geography as one of their specialisation areas in preservice training and GIS was included. Also, it was found that the subject specialisation had a bearing in the way GIS was being taught. The research also revealed that the lack of teaching and learning materials in the study area negatively impacted on the diffusion and integration of GIS education in schools in Frances Baard District. Many schools do not have GIS laboratories, GIS software and some do not have reliable internet and electricity connectivity. Also, the research revealed that teachers were not prioritising the GIS section or teaching through GIS because it has small weighting in the curriculum. It only constitutes 15 marks of the entire 300 marks in the geography examination at matric level. This means that GIS contributes only 5% of the total marks. This low percentage is not motivation enough for the teachers to seriously invest their time and energy in GIS teaching.

CHAPTER 6: SIGNIFICANT THEORETICAL INSIGHTS

6.1 INTRODUCTION

The main thrust of this chapter is to present and discuss the insights of the study as they emerged from the data generated and interpreted from the research. The insights that emerged from these findings are discussed in detail in the following section. Triangulation and the use of multiple data generation methods by using data from questionnaires, interviews and lesson observations yielded rich data and insights. In total, 50 participants participated by completing the questionnaire survey and 10 participants were interviewed (most before and after their lesson observation) and had their GIS lessons observed in a classroom setting. The study findings show that the 10 teachers who participated in the qualitative segment of this study were all university graduates, with 90% possessing a teaching qualification, one teacher had an academic degree but no professional teaching qualification. All the teachers interviewed had vast experience of teaching in general geography but did not have much experience of teaching GIS.

The next sections weave a valuable narrative of 'perfunctory GIS teaching' in the Frances Baard District from significant theoretical insights into the participants' use of certain pedagogical approaches and teaching methods for GIS in the FET phase which impacts on the adoption and diffusion of GIS in schools. 'Perfunctory GIS teaching' was evident in the mechanical, minimal effort, lacking- in- enthusiasm manner in which many teachers raced through the GIS section of the CAPS (from the questionnaires, interviews and observations) and this emanated from a host of reasons at different levels which serve to defeat the successful adoption and diffusion of GIS: teachers' attributes such as age and training impacted on their lack of GIS content knowledge and pedagogical content knowledge, the nature of the context-classroom and school environment, the curriculum (CAPS) requirements and the Department of Basic Education's orientation to GIS (curriculum and assessment demands predominantly).

6.2 INSIGHTS EMERGING

Age and appropriate GIS training as criteria for successful GIS teaching

Teachers' qualifications play an important role in their teaching of geography and, more specifically, GIS in South African high schools. This notion was observed during the lesson observations with 10 teachers in this study. The teachers who had undertaken GIS courses during their training at universities were better at explaining the concepts of GIS to learners than those teachers who had attended one department GIS workshop. The teachers were nevertheless forthcoming about trying new methods of teaching that were inclined to learner centred.

Qualifications and teaching experience play an important role in the teaching of geography and, in particular, GIS. The findings indicate that teachers who have more teaching experience are good at organising their learners in terms of classroom management. Mr Ngubane one of the teachers, who was well organised ensured that learners were all disciplined in his class during the GIS lesson. A scrutiny of his GIS lesson though revealed that there was not much learning which was taking place in the class. Learners were disciplined not because they were concentrating on the teaching and learning, but it was because the learners were afraid of Mr Ngubane. Mr Ngubane was authoritarian in his approach. The pedagogical approaches he used during the lesson would not allow learners to participate or ask questions during the lesson. For the 35-40 minutes lesson, I spent in Mr Ngubane's class, no learner dared to pose a question. He just read the textbook on Spatial and Spectral resolutions and gave a few explanations and spent much time writing notes from the textbook on the chalkboard.

By contrast, Teacher Tau, at School 2, used a PowerPoint presentation and clearly explained the concepts he was teaching, using different examples and pictures. Although there was less organisation in the classroom, the lesson was well thought off, because the teacher had content knowledge of the subject and he was able to use modern technology to teach the learners. The teacher employed different learning styles in the lesson, and this captured the learners' attention throughout the lesson.

What emerged from the lesson observations was that the number of years one had spent teaching the subject did not translate into articulating the GIS content sufficiently to be taught. GIS concepts were recently introduced in the high school geography curriculum in South African schools and older teachers were struggling to teaching GIS more than younger teachers. Many of the older teachers did not have GIS as part of their teaching qualification with regard to curriculum when they were training at the universities and colleges. The literature review also revealed that since GIS was recently introduced into the high school geography curricula worldwide, teachers are using the traditional teacher centred approaches to teach GIS. The majority (90%) of the teachers interviewed in this research stated that they had not received training in GIS from universities and colleges. The only training, they had access to, were workshops offered by the Department of Education, which teachers felt were not enough to make them competent to teach GIS. For the past five years (from 2015-2019) the teachers in Northern Cape province had only attended at most three workshop training sessions in GIS. Most of the teachers in the study area complained that the workshops were not effective since there were no follow sessions to check and further support geography teachers. As a result, many teachers relapsed in knowledge retention.

6.3 GIS TEACHING: DIFFUSION, ADOPTION AND USE

The finding of this research is that the adoption, diffusion, and use of GIS in high schools in schools in the Frances Baard District is slow and, in some instances, it has stagnated. The teachers who are supposed to be at the forefront of promoting GIS and ensuring the diffusion of technology, are held captive by a lack of GIS training, their own thinking about its teaching and inadequate GIS resources.

GIS diffusion in high schools in Frances Baard is at various stages. According to Rogers (2003), diffusion happens through a five-step decision-making process and a number of communication channels among the people involved over time. The geography teachers in the study were aware of GIS as a technological advancement and its importance. The majority of teachers therefore passed stage one of DOI theory, which is the awareness stage, while some teachers were at stage two, which is the interest stage, whilst some were at the trial and adopting phase, using the technology. However, there are various reasons why the teachers are at different stages of the DOI. These factors include a lack of GIS knowledge, a lack of physical resources, large classes and the length of the geography curriculum. The findings of this study indicate that the communication channels through which information should flow from the Department of Education to teachers in the classroom are not well defined. When the teachers were asked whether they knew where to obtain information on GIS to upskill or gain the necessary knowledge, the majority indicated that they did not know where they could get help. Hence, if the channels of communication are not clear, it will be an important step for GIS to diffuse to the schools. It is apparent that the Department of education has not provided the necessary knowledge, pedagogical and communication scaffolding to geography teachers that should accompany a new curriculum addition.

6.3.1 TEACHERS' LACK OF KNOWLEDGE ON GIS

The insights emerging from the research suggest that many teachers lack knowledge of GIS and a deep understanding of its application. There is a knowledge gap, particularly in older teachers, because GIS technology is new being only recently introduced in the geography curriculum. When the teachers were asked about their knowledge of GIS, the majority (84%) stated that they have a fair knowledge, but they need GIS training. Deep probing indicated that they lack knowledge of GIS and it cuts across race and age of the teachers. All indicated that they are in need of training in GIS. They claimed that the training they had received from the Department of Education was inadequate. However, the lack of knowledge of GIS does not only affect teachers at South African high schools. A study by Mzuza and van der Westhuizen (2019) about the state of GIS education in Southern Africa as a region revealed that geography teachers do lack GIS skills. Also, a study which by Demirci (2008) states that teachers in Turkey lack an in-depth understanding of GIS concepts and that they have inadequate skills regarding technology that affects teachers' output. Furthermore, Feiman-Nemser and Parker (1992) much earlier stated that an understanding of the subject matter is important and necessary for a teacher to function well. A lack of GIS knowledge reduces teachers' confidence when they teach GIS concepts (Ottesen,2006; Zhang, 2007; Paraskeva et al., 2008; Sadik, 2008). Hence, as Shulman (1999) affirms, the interaction between content matter and pedagogy is very important.

Additionally, many teachers resorted to 'teaching about GIS' rather than 'teaching through GIS' for several reasons, discussed below.

6.3.2 SCHOOLS' LACK OF PHYSICAL RESOURCES

Learners in high schools need hands-on experience in order for them to understand GIS better, thus the application of GIS is important and not mere memorisation of content. The majority of the teachers interviewed in this research failed to embrace 21st century pedagogical approaches for GIS teaching, mainly due to lack of physical resources, such as computers, GIS software, data projectors and GIS laboratories. The teachers identified the lack of physical resources as one of the barriers that prevented them from innovating and integrating modern teaching strategies. Most of the teachers deployed traditional ways of teaching, which did not allow the learner to construct their own knowledge. Teachers who teach at former model C schools and private schools, which are well resourced, were more innovative in their approaches to teaching GIS.

6.3.3 LARGE CLASSES IN PUBLIC SCHOOLS

A large class size is one of the problems in township and rural schools in Frances Baard District which negatively affects the diffusion of GIS. When the class is large and under resourced and the teacher lacks confidence in a topic like GIS, it was evident that the teacher struggled to assist a learner who may need help to understand GIS and resultantly GIS diffusion was negatively affected. Also, teachers stated that they cannot be creative or experiment with new teaching methods because of the large numbers of learners in public school classes. For instance, group work as a teaching approach requires small numbers of learners in a class, and a large number of learners take time and space to organise into meaningful learning groups for activities. Also, large classes in township schools have shortages: resources such as textbooks, chairs and desks which impact on teaching and learning.

6.3.4 GIS TEACHING NOT A PRIORITY

The geography syllabi of Grades 10-12 are lengthy, and content filled, to the extent that teachers do not have sufficient time to teach GIS concepts given other topics in the curriculum. The majority (76%) of the teachers, as shown in Table 4.10 and Table 4.11stated that GIS needs more time to teach and to learn as it is a new innovation. The research also found that both male and female teachers felt that they do not have enough time for themselves to learn about GIS. When the knowledge of GIS among teachers was analysed against age of the participants, the findings were that older teachers (40-49 and above 50 years)- needed more training than the young teachers (26-29, 30-39 years). A lack of time to learn about GIS was also echoed by Scheepers (2009) in research which was done at Ashton secondary school in the Western Cape province of SA. Geography teachers mentioned a lack of time and a lack of knowledge in computers and GIS. In addition, because GIS is not assessed practically in examinations and GIS only contributes 15% of Paper 2 of the examination, makes it difficult for teachers to give time and attention to the teaching of GIS effectively. Hence, they resorted to encouraging learners to memorise content for the examinations as its only 15% of the marks in total. Therefore, GIS is not prioritised by teachers in their lessons. Teachers would rather spend more time teaching other content in geography, because it contributes more marks in the examination paper. As long as GIS is not assessed at the practical level and it contributes a low weighting in the geography grade 12 exit examination, teachers will not make the effort to learn and to teach it effectively. This trend was discovered in Japan, Taiwan, Turkey and Chile (Chen, 2012; Ida & Yuda, 2012).

6.4 PREFERRED PEDAGOGICAL APPROACHES

This section discusses the preferred pedagogical approaches of teachers in this research. It should, however, be noted that the concept of pedagogical approach is very broad and understood differently by different people. In this research, the teacher-centred and learner-centred methods are the two competing pedagogical approaches that were used by most of the teachers. These pedagogical approaches were evident when the teachers taught using different teaching methods. The teachers who used teacher-centred pedagogical approaches employed direct instruction, explanation and questioning, and used various teaching methods and strategies to transmit the knowledge to the learners who were new to GIS as a Geography topic. By contrast, learner-centred pedagogical approaches involved teaching methods such as class discussions, demonstrations, field work and projects as the main teaching methods for teaching.

Finally, the majority (80%) of the teachers in this research used teacher-centred pedagogical approaches for teaching GIS. The teaching methods used by many teachers included direct instruction/lecture method, questioning and explanation.

Teachers stated that they use this pedagogical approach because of time constraints as they needed to complete the geography syllabus which they said was very lengthy. GIS is a new curriculum inclusion in Geography, there is no continuity from grade 9 into grade 10 and this also makes most of the learners reliant on the teacher as the provider of information. Direct instruction/lecture method is mainly used when teachers are introducing a new concept and when time is limited (Darling-Hammond et al., 2020). Teachers felt that it is their responsibility to pass that knowledge to the learners without involving the learners in the construction of that knowledge, so there is no co-construction of knowledge. The teachers argued that the other teaching approaches, such as group work and fieldwork, are time consuming and they waste time because they required huge amounts of investment in time and preparation bearing in mind the length of the curriculum (syllabus). Due to the high stakes national grade 12 exit assessment and mark allocation, certain decisions on priority pedagogical methods needed to be made by the teachers and this frequently were at a cost to GIS learning through exiting teaching methods.

The lecture method is one of the most frequently used method/strategy of teaching by teachers (Jacobsen, Eggen, Kauchak & Dulaney, 1981; Joseph & Jon, 2017) also describe it as the most misused method of teaching by the teachers. However, the lecture method/direct instruction can save time and resources and the teachers used this method more regularly because it augurs well with the extensive geography syllabus that needed to be completed in a limited time frame. The reality for teachers is that if they do not employ this method of teaching, they believed that they will not be able to complete the syllabus. It should also be noted that the lecture method is not the most suitable method to teach GIS. Rosenberg (2010) compiled a list of information transfer methods that includes, among other things, awareness and social marketing, talks and presentations, demonstrations and experiments, guided questions, games, and quizzes. Surprisingly, the most appropriate methods, such as Field work, demonstration, project teamwork and presentation teaching methods, were missing in most of the lessons that I observed during the research to this study. A further reality is that field work, a signature pedagogy of Geography, is hailed as one of the most appropriate teaching strategies for GIS.

The other reason cited by teachers interviewed and surveyed as to why they preferred direct instruction is their lack of content knowledge of the GIS concepts to be taught. The majority (80%) of the teachers who participated in the research highlighted that they do not understand the concepts which they are supposed to teach in the GIS section of CAPS. The researcher can attest to this claim. The teachers in most of the lessons observed were struggling with the content knowledge they were teaching. Most of the teachers (80%) admitted that they do not understand the concepts of GIS because these concepts are new to them and they do not have time to learn the concepts by themselves. As a result, the majority of teachers employed teacher-centred pedagogical approaches which emphasise memorisation of answers so that the learners can pass the section of GIS in the examination. These types of teaching methods do not advance learners' critical thinking skills or deep learning. The recent emphasis on pedagogy focuses more on a constructivist approach than on a behaviourist approach (Johnson, 2009). Furthermore, teachers in secondary schools should use the problem-based learning (PBL) and inquiry-based learning (IBL) methods, which are based on constructivism and are challenging. Learners' roles in more learner-centred pedagogical approaches shift from passive recipients of geographic information to more active members of an interacting group capable of processing and interpreting geographic information in a real-world situation and positioning learners to build on knowledge through inquiry and reflection.

6.5 TEACHING RESOURCES AS ESSENTIAL

The availability of teaching resources, especially instructional materials like textbooks are essential in the teaching of any subject as are other resources that facilitate GIS teaching and learning. The lack of classroom resources renders the teaching and dissemination of information very difficult for learners in secondary education.

Geography classrooms are an important place and space in learning geography especially for diffusion, adoption and use of GIS technology. The classrooms are a source of inspiration and information. A well-equipped geography classroom motivates the learners, sparking interest to learn the subject. The findings from the research showed that most of the teachers do not have a stand-alone geography classroom. Teachers and learners migrate to a different classroom after every lesson. It is difficult to thus effectively teach geography and GIS without the use of charts, globes, models and GIS software. The absence of a stand-alone geography classroom/laboratory or a shared ICT laboratory makes it extremely difficult to deliver an effective lesson in GIS. Therefore, teachers need a supportive and conducive environment that can motive the learners (Jenkinson & Hewitt Jenkinson & Hewitt, 2010). In addition, most classrooms observed in township schools and rural areas were overcrowded and under resourced, thus making the teaching of GIS difficult.

6.6 RECOMMENDATIONS FOR THE DIFFUSION OF GIS IN HIGH SCHOOLS

This section outlines some of the recommendations which need to be adopted if GIS has to diffuse faster in high schools. Based on the findings of the research, the majority of the teachers who were interviewed and who responded to the questionnaire survey, agreed unreservedly that the introduction of GIS in the high school curriculum at the FET phase was a good idea and that the learners enjoyed learning about GIS. However, the majority bemoaned that GIS is taught theoretically. The study is cognisant that many teachers suggested that GIS should be taught and assessed practically and that learners should be exposed to the practical nature of GIS where they are taught in a laboratory and do field work, but for this to occur teachers need to also be trained adequately in teaching GIS and using the best pedagogical approaches to promote learning about GIS and through GIS.

Based on the findings in this research, the following recommendations are advanced to the various stakeholders of education and different sectors involved in the implementation of GIS in schools:

1. Institutions of Higher learning

For teaching in higher education institutions such as universities and training colleges, GIS modules be made compulsory for all teachers majoring in geography and social sciences in preservice teacher training regardless of their phase specialisation because schools do not hire teachers based on phase specialisation in SA. If GIS modules are made compulsory in geography, it will equip the teachers with enough GIS content knowledge of GIS, technical expertise to apply GIS and the pedagogical knowledge to teach GIS. This will go a long way in trying to bridge the technological gap which exists at the moment. Public Institutions of higher learning have the funding and thus the capacity and ability to capacitate the teachers. Of course, it is a known problem that GIS modules offered in most university degree programs are not tailored to the needs of teachers because they are meant to cater for learners who are enrolled for BSc Environmental Sciences, BSc Geography, BSc. Biological Sciences etc. Thus, institutions of higher learning do need to design a GIS curriculum specific to the CAPS for learner teachers which can lay the foundation so that teachers gain baseline GIS knowledge, pedagogical and application skills in teaching GIS in high schools.

The institutions of higher learning can also assist through in-service workshopping of the geography teachers on the practical activities of GIS during the school holidays. Such endeavours can be incorporated into the geography Departments of various universities and colleges that offer GIS. In addition, the geography department in various universities can offer GIS training for teachers as a community engagement project where they adopt certain schools in the area and offer GIS training to teachers and learners based on the CAPS.

2. Department of Basic Education

The Department of Basic Education should avail more resources to schools or to a cluster (comprising multiple schools) which offer geography so that they can build GIS laboratories, buy computers and install GIS software. Also, the department of Basic Education must acknowledge its role to workshop all geography teachers who are currently teaching in high schools. If the Department of Basic Education is incapacitated to do it, other institutions of higher learning such as universities and the private sector can assist through partnerships to provide the teachers with the necessary GIS training, knowledge and skills. Also, GIS is currently taught theoretically. GIS by nature, is practical and teaching and assessment needs must have practical and theoretical components, one without the other will compromise its implementation.

Another practical way which can be implemented by the stakeholders such as the Department of Basic Education, is to start the GIS seeding of schools. The department can identify a few schools in the province and supply such schools with all the necessary GIS technology equipment and training. The department can also create a GIS laboratory in these schools and employ GIS technicians who will teach GIS concepts and application in these schools. The other schools in the area can transport their learners to the selected schools to be taught. In this way the learners can be exposed to both the practical and theoretical aspects of GIS. The department of education would need to monitor and supervise the teaching and learning of GIS in these schools for at least a year until teachers are more confident of their GIS teaching.

3. Private sector

The Private sector can contribute to GIS diffusion. For example, ESRI can provide the necessary GIS data sets which can be used by the teachers to teach GIS topics.

4. Schools

Schools which are located near universities could arrange with the university as part of social responsibility to engage learners to do some GIS practical activities in the universities' GIS laboratories. This can help to motivate the learners to like geography especially GIS and this will contribute towards helping to improve the pass rate in GIS questions.

5. Teachers and pedagogical approaches

Teachers should be continuously developed and supported through in-service training. This can be done through workshops. Some teachers can be trained by local universities during school holidays when the teachers are free from their daily teaching commitments. For instance, universities can arrange GIS training by offering a short GIS course for continuous professional development points for the teachers where they can be given certificates upon completion of the course. Also, it will be ideal if the teachers could be assisted with GIS laboratories and GIS software so that they can put into practice what they have learnt in those GIS workshop trainings. Adopting a Design-Based Research Portfolio (DBRP) pedagogical approach can help teachers improve their instructional practices as well as helping the learners to construct their own knowledge as they complete DBRP.

6. Future research

I recommend that this research study is carried out in other provinces to explore the pedagogical approaches used by teachers for GIS teaching, to gauge teachers' level of GIS knowledge and training and to unpack the similarities and differences in GIS teaching and diffusion amongst the various schools to develop suitable GIS support for teachers.

6.7 CONCLUSION

This chapter discusses the insights that emerged from the research findings. According to the findings of this study, age plays a significant role in the adoption and teaching of new technology. Teachers aged 40-49 and over 50 years struggled to understand GIS technology in order to teach and explain some GIS concepts, compared to relatively young teachers aged 26-30 and 35-40 years. In most of the lesson observations, relatively young teachers were able to explain GIS concepts. These teachers were well-versed in technology because they had taken some GIS courses while studying at universities and colleges. Another insight that emerged from the research was teachers' pedagogical experiences. Teachers with more experience taught more organized lessons than teachers with less experience.

The majority of the teachers in this study used teacher-centered pedagogical approaches regardless of the number of years of teaching experience. When teaching GIS topics, teachers used direct instruction such as explanation, questioning, and the lecture method more frequently than learner-centered pedagogical approaches that allow learners to contribute to the co-construction of their knowledge through experimentation and discovery learning. The reasons for selecting teaching approaches included, among others, a lack of content knowledge, a lack of pedagogical knowledge, a lack of instructional resources and large classes. A lack of pedagogical knowledge in GIS has a negative impact on the choice of teaching methods: when teachers lack subject content knowledge, they had a tendency to rely on traditional methods of teaching. The mechanical, minimal effort, lack of enthusiasm in which many teachers raced through the GIS section demonstrated perfunctory GIS teaching. The lack of resources had a direct negative impact on the adoption and diffusion of GIS technology aligned to the various stages of Rogers diffusion of innovation (DOI). Some teachers were in the awareness stage, while others were in the stage 2 -interest stage, and still others were in the trial and adoption stages. Another factor that contributed to teachers being at different stages was the lack of clear and well-defined communication channels through which information could flow from the Department of Education to teachers and into the classroom. Some teachers complained about inadequate DBE support help to upskill or gain necessary knowledge in GIS. If communication channels are open, it will be easier to spread GIS technology to schools. Another insight from this study was that the teachers did not prioritize GIS instruction. Geography syllabi in grades 10-12 are lengthy and content-rich but teachers did not have enough time to teach GIS concepts as part of the curriculum. Because GIS is a new innovation, it requires more time to teach and learn. Furthermore, the GIS section accounts for 15% of paper 2 of the matric examination which makes it more difficult for teachers to devote sufficient time and attention for effective GIS instruction. Teachers opt to spend more time teaching other geography content because it contributes more marks in the final national assessment. Another finding from this study was the scarcity of physical resources. The subject of geography, particularly the GIS section, is not taught in a separate classroom. Delivering a successful GIS lesson in shared geography classrooms and/or ICT laboratories is challenging. A friendly and favorable environment that can motivate learners is required for GIS technology to disseminate swiftly into schools. GIS laboratories, GIS software, electricity connectivity, internet access, and, most importantly, qualified and skilled teachers and teacher assistants are among the resources which were disparately needed in high schools for GIS technology for efficient, swift diffusion.

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APPENDIX A: QUESTIONNAIRE INSTRUMENT

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Questionnaire about the status and methodologies used in teaching Geographic information systems (GIS) in high schools in geography curriculum.

My name is Johane Hlatywayo, a student and I am completing a research study from the University of KwaZulu-Natal. The purpose of this research is investigating the pedagogical approaches used by educators to teach Geographic Information Systems (GIS) in geography in high schools in order to refine teacher-training practice. The questionnaire also sorts to investigate the GIS concepts being taught and educators' beliefs' of GIS development and challenges they face in high schools. The results of the survey will help in the development of educational program on GIS and assist in-service training for educators and give direction to the work to be done hereafter. Your responses will be confidential. You do not need to write your name on the questionnaire, so your responses will never be linked to you personally. Only myself and my supervisor involved in this study will see your responses. Your participation in this study is of paramount importance and it's voluntary. If you do not want to participate, please return the questionnaire to the researcher. You also do not have to answer questions that make you uncomfortable.

Thank you in advance for participating and contributing in this survey.

A- Personal Questions***:*** *Please tick of the correct option in the bracket.*

1- Gender

Male (   )   Female (   )

2- Age

20-25 (   )   26-32 (   )   33-40 (   )   41 and above (   )

B- School, lessons and questions regarding professional experience: *Please tick off the correct option in the bracket.*

1- Is your school private, state or independent school? Place a tick off the correct option

Private school (   )   Public school (   )

2-Teaching experience and qualification.

1-4 years ( )   5-9 years ( )   10-14 ( )   15 and more years ( )

3- How many hours a week do you teach geography?

1-8 ( )   9-16 ( )   17-24 ( )   25 and above ( )

4- The average number of learners that your teaching in each class.

Less than 15 ( )   16-30 ( )   31-45 ( )   46 and above ( )

5- What is your highest qualification.

Diploma/Certificate (   )   Graduate (   )   doctorate (   )

6- Area of Specialisation.

geography (   )   Social studies (   )   other areas (   ) Please specify the field

C- Questions about the GIS physical infrastructure at your school

1- Does your school offer Information Communication Technology (ICT)

Yes ( ) No ( )

2- Which of the tools listed in the table below are available in your geography class? Mark the correct box with an "X".

Tools and Supplies	Have	No
Computer		
TV-Video		
LCD Projector		
İnternet		
Overhead		
printer		

3- Do you conduct GIS lessons in the ICT lab?

Yes ( ) No ( )

4- Are the Computers lab maintained regularly?

Yes ( ) No ( )

5-Have ever experienced some technical problems in the lab?

Yes ( ) No ( )

6- Do you have a technical or administrative person who maintain the computers?

Have ( ) No ( )

7- Does your school have a GIS license?

Available ( ) Not present ( )

D- GIS aspects, Pedagogical approaches/methodologies and professional experience of GIS in geography

Briefly answer the following questions:

1. What aspects of GIS are you teaching in the geography curriculum?

____

____

2. Which pedagogical approaches/methodologies do use to teach the aspects of GIS you have listed above

____

____

3-Can you briefly state the reasons why you chose the methodologies you are using instead of the other approaches in teaching these aspects.

____

____

4- Do you think you have enough information about GIS?

Yes ( ) No ( )

5- How do you feel about the inclusion of GIS in the FET phase?

____

____

6-Have you been able to implement the teaching of GIS with ease?

Yes ( ) No ( )

7-How would you rate your knowledge of GIS?

Very weak	Weak	Fair	Good	Excellent

8- Explain your answer to Q7?

____

____

9- How would you rate your implementation of GIS teaching?

Very weak	Weak	Fair	Good	Excellent

10- Explain why you have rated yourself in this way in Q9?

____

____

____

11- What are your experiences of teaching aspects of GIS at this school?

____

____

12- Have ever used a GIS software before?

Yes ( )   No ( )

13- Do you have any GIS software?

Yes ( )   No ( )

14- Have you ever used the GIS software before in your geography lesson with your learners?

Yes ( )   No ( )

15- Do you think your geography lessons will benefit from GIS?

Yes ( )   No ( )

16- What challenges do you face in teaching GIS in geography in high school?

E- Teachers' professional experience on GIS

1- Have ever received any training in GIS?

Yes ( ) No ( )

2-What form of training did you receive?

Course ( ) Workshop ( ) other form of training ( ) none ( )

3- Briefly describe the type of training you received.

4- How long was the training (workshop/Course)?

1-2 days ( ) 1 week ( ) 2 weeks ( ) 6 months 1 year ( )

5- Was the training adequate?

Yes ( ) No ( )

6- How often do you go for training in GIS?

Weekly ( ) Monthly ( ) Termly ( ) Yearly ( )

7- Who normal gave you the training in GIS?

Department of education ( ) University ( ) others ( ) none ( )

8- Did you attend these courses?

Yes ( ) No ( )

9- Do you know exactly where to get help when you want to gain more knowledge and experience with GIS?

Yes ( ) No ( )

F-Teachers' attitudes on GIS

The following is a Likert scale summarizing the Attitudes on the inclusion or use of GIS in geography curriculum. Your participation in this case Likert scale will give opinion on GIS inclusion in the geography curriculum. The Likert scale runs from (I totally agree, I agree, I have no idea, disagree and strongly disagree). Put "X" on the box best describe your belief.

Statements		Participation Degree				
		Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Dis-agree (2)	Strongly disagree (1)
1	GIS is an effective teaching tool that I can use in geography lessons.					
2	Computers with the GIS software, projector are essential to have in teaching GIS in class.					
3	geography teachers need training on how to teach and use GIS.					
4	The use of GIS in geography courses are required.					
5	A system that is not easily available to the extent of GIS and geography teachers and learners can be understand.					
6	GIS supports learner-centred teaching methods					
7	GIS concepts motivate learners to like geography more.					
8	GIS lessons support critical thinking and problem solving in learners.					
9	GIS teaching needs hands-on experience with a computer in the class.					
10	The teaching of GIS takes a lot of time to learn.					

APPENDIX B

INTERVIEW SCHEDULE PRIOR TO LESSON OBSERVATION

Name of Teacher: ____________________________

School: ____________________________________

Additional info: _____________________________

Demographic Data:

Male/ Female:_______________ Marital Status:______________

Age:_______________________ Race/ Ethnicity:______________

Nationality:____

Qualification/s:____

How long have you been teaching geography in the FET phase? ____________________

1. **What aspects of GIS are you going to teach in this lesson?**

   ____

2. **What are pedagogical approaches (methodologies) are you going to teach these aspects of geography?**

   ____

3. **Why have you chosen these pedagogical approaches instead of the other approaches in these aspects?**

   ____

   ____

How do you feel about the inclusion of GIS in the FET phase?

____

____

____

____

4. **Have you been able to implement the teaching of GIS with ease? Yes/no.**

5. HOW WOULD YOU RATE YOUR KNOWLEDGE OF GIS?

V.WEAK	WEAK	FAIR	GOOD	EXCELLENT

6. Explain your answer to Q6?

____

____

7. HOW WOULD YOU RATE YOUR IMPLEMENTATION OF GIS TEACHING?

V.WEAK	WEAK	FAIR	GOOD	EXCELLENT

8. Explain why you have rated yourself in this way in Q8?

____

____

____

What are your experiences of teaching aspects of GIS at this school? (also note if you can ascertain the teacher's attitude)

____

____

____

____

____

____

____

____

____

____

____

____

____

APPENDIX C

LESSON OBSERVATION SCHEDULE (1)

Name of Teacher: ___________________________

School: _____________________________________

Additional info: _____________________________

1. How does the teacher implement GIS?

____

____

____

____

____

____

Teaching Methods/approaches used in GIS lesson: singular/ multiple approaches

And are they satisfactorily undertaken? YES/SOMEWHAT/NO.

Explain____

____

3. Comments of the Teacher's implementation of GIS

____

____

APPENDIX D: CLASSROOM OBSERVATION SCHEDULE (2)

Stage	Approximate time	Teachers' practice	Learners' practice
Lesson observation			
Lesson presentation			
Practice			

Reflection			

After class mini-interview notes (reflection of classroom processes

APPENDIX E

SEMI STRUCTURED INTERVIEW SCHEDULE AFTER LESSON OBSERVATION

Name of Teacher: ______________________________

School: ______________________________________

Additional information: ______________________________

Recall the aspects of GIS that the teacher was going to teach in the lesson.

____

1. **Did you achieve teaching all the aspects you intended? Explain**

____

____

____

Recall the pedagogical approaches (methodologies) that the teacher intended using.

2. **Why did you choose to use these particular pedagogical approaches in your lesson?**

APPENDIX F

GEOGRAPHY PASS RATE IN SCHOOLS IN FRANCES BAARD DISTRICT

from 2014 to 2018 (source: Northern Cape Department of Education, 2019)

	2018		2017		2016		2015		2014	
Centre-name	Wrote	Pass%	Wrote	Pass%	Wrote	Pass%	Wrote	Pass%	Wrote	Pass%
H/SCHOOL EMANG MMOGO	94	60,6%	75	81,3%	84	75,0%	59	76,3%	56	48,2%
H/skool Delportshoop	43	81,4%	85	88,2%	59	84,7%	72	83,3%	22	63,6%
H/SCHOOL FLOORS HIGH	40	82,5%	32	100,0%	57	94,7%	72	75,0%	37	94,6%
H/skool Noord-Kaap	73	95,9%	55	100,0%	48	100,0%	54	100,0%	44	100,0%
Kimberley Girls' High School	42	100,0%	40	100,0%	30	100,0%	42	100,0%	37	100,0%
H/skool Barkly-Wes	20	65,0%	24	100,0%	24	100,0%	21	100,0%	21	95,2%
Reakantswe Intermediate School	20	35,0%	16	81,3%	21	47,6%	19	47,4%	14	64,3%
H/skool Adamantia	28	100,0%	27	100,0%	33	100,0%	26	100,0%	19	100,0%
H/SCHOOL HOMEVALE	148	54,7%	91	80,2%	117	75,2%	169	71,0%	103	52,4%
H/SCHOOL THABANE	17	88,2%	7	100,0%	17	94,1%	17	100,0%	12	91,7%
H/SCHOOL VUYOLWETHU	140	50,7%	136	86,0%	149	80,5%	154	90,9%	117	58,1%
H/SCHOOL DIKGATLONG	48	52,1%	44	70,5%	49	71,4%	37	86,5%	24	75,0%
H/SCHOOL BORESETSE	107	33,6%	101	75,2%	118	53,4%	100	71,0%	151	35,1%
H/skool Rietvale	74	74,3%	50	94,0%	47	95,7%	79	58,2%	48	75,0%
H/SCHOOL ST BONIFACE	108	85,2%	99	92,9%	148	85,1%	96	87,5%	91	81,3%
H/SCHOOL WILLIAM PESCOD	80	80,0%	54	96,3%	54	96,3%	114	85,1%	82	64,6%
DEGANIA HIGH SCHOOL			3	100,0%						
H/skool Diamantveld	39	100,0%	60	100,0%	49	100,0%	64	100,0%	56	98,2%
Kimberley Boys' High School	50	96,0%	44	100,0%	42	92,9%	54	96,3%	32	87,5%
H/skool Pescodia	108	72,2%	36	100,0%	75	82,7%	66	78,8%	50	74,0%
H/SCHOOL TSHIRELECO	22	81,8%	28	89,3%	42	85,7%	47	83,0%	25	80,0%

H/SCHOOL E P LEKHELA	67	77,6%	50	98,0%	69	78,3%	90	66,7%	40	77,5%
Ixunkhwesa Combined School	16	18,8%	9	100,0%	30	36,7%	23	26,1%	5	60,0%
H/SCHOOL TETLANYO	95	81,1%	91	92,3%	129	86,0%	71	95,8%	66	80,3%
H/SCHOOL GREENPOINT	14	64,3%	3	100,0%			18	55,6%	5	40,0%
ROODEPAN HIGH SCHOOL	58	65,5%	17	41,2%						
H/SCHOOL BANKSDRIFT	75	56,0%	69	60,9%	59	42,4%	105	45,7%	86	50,0%
Vaalharts Gekombineerde Skool	10	80,0%	8	100,0%	19	100,0%	20	100,0%	11	72,7%
H/skool Warrenvale	16	93,8%	35	91,4%	15	93,3%	18	83,3%	20	85,0%
H/skool Hartswater	34	100,0%	21	100,0%	16	93,8%	21	100,0%	22	90,9%
H/skool Vaalharts	42	97,6%	28	96,4%	25	100,0%	42	100,0%	23	100,0%
H/skool Warrenton	20	90,0%	13	92,3%	12	75,0%	23	69,6%	9	66,7%
H/SCHOOL MOGOMOTSI	89	74,2%	77	92,2%	70	75,7%	89	82,0%	41	95,1%
H/SCHOOL TLHWAHALANG	79	50,6%	22	90,9%	93	74,2%	163	63,2%	78	56,4%
H/SCHOOL FLOORS NO2	33	57,6%	27	70,4%	16	43,8%	4	100,0%		
VALSPAN HIGH SCHOOL	134	39,6%	17	64,7%						
H/SCHOOL KGOMOTSO	243	60,1%	184	82,1%	210	84,3%	239	74,1%	259	59,1%
H/SCHOOL PAMPIERSTAD	108	59,3%	145	65,5%	99	74,7%	108	85,2%	72	70,8%

APPENDIX G

ETHICAL CLEARANCE

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

04 December 2014

Mr Johane Hlatywayo ([redacted]
School of Education
Edgewood Campus

Dear Mr Hlatywayo,

Protocol reference number: HSS/0563/014D
Project title: Geographic Information Systems (GIS) in high schools within a framework of technological diffusion

Full Approval – Expedited Approval

With regards to your application for ethical clearance received on 05 June 2014. The documents submitted have been accepted by the Humanities & Social Sciences Research Ethics Committee and **FULL APPROVAL** for the protocol has been granted.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

Please note: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

[redacted]

....

Dr Shenuka Singh (Chair)

/ms

Cc Supervisor: Dr Sadhana Manik
Cc Academic Leader Research: Professor P Morojele
Cc School Administrator: Ms Bongi Bhengu

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
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APPENDIX H

PERMISSION FROM NORTHERN CAPE DEPARTMENT OF EDUCATION

I.K Nkoane Education House
155 Barkly Road
Homestead
Kimberley 8301

Private Bag X5029
Kimberley 8300
Republic of South Africa

Tel: 053 839 6500
Fax: 053 839 6580/1
Web: ncdoe.ncpg.gov.za

DEPARTMENT OF EDUCATION

Enquiries: DR MI ISHMAIL
Reference: Permission to conduct research.
Letter date: 19 June 2014
Date: 04 AUGUST 2014

Sol Plaatjie University
31 Scanlam Street
Room A6
New Parkland Campus
Kimberley
8301

Dear Mr J Hlatywayo

The Topic: Geographical information Systems (GIS) in High Schools in High Schools within the framework of technological diffusion.

You are herewith granted permission to do research as per your request dated 07 July 2014.

The Northern Cape Department of Education however requests that the findings and recommendations be shared with the Curriculum and Assessment Chief Directorate at the Provincial Office.

Yours faithfully

[redacted]

Dr MI Ishmail
DDG: Curriculum, Examinations and Assessment