SCIENCE PLEDGE

By my signature below, I certify that my thesis is entirely the result of my own work. I have cited all sources I have used in my thesis and I have always indicated their origin.

\[\text{Signature}\]

(Kempton Park, 30 March 2019)
ABSTRACT

In South Africa, studying Geographical Information Systems (GIS) is included in the geography curriculum between grade 10 and 12. The literature cites challenges, such as a lack of curriculum-orientated reasonable GIS software, necessary computer hardware, teachers’ GIS teaching knowledge, and many other challenges, as key in the non-implementation of GIS in the classroom. Despite these implementation challenges, there are other methods for teaching GIS that can be considered and implemented, such as mobile GIS. Mobile GIS case studies that have been conducted in other countries indicate that mobile GIS could be an effective way of introducing GIS in the classroom.

Mobile GIS was introduced in five secondary schools in Tembisa, Gauteng Province, South Africa, that teach geography at grade 11. In this study, a mobile GIS exercise was created to give learners an opportunity to operate handheld devices (smartphones) loaded with Collector for ArcGIS to identify and capture point, line and polygon features with attribute data within their school premises. Although some challenges were encountered during the study, learners easily related and adapted to the new way of learning GIS. They were able to carry out the instructions of the exercise and showed eagerness to use mobile GIS as part of their lessons.
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- The principals, vice-principals, geography heads of department, and educators of Tembisa secondary schools who participated in the study
- All 82 geography grade 11 learners who participated in the study
# TABLE OF CONTENTS

SCIENCE PLEDGE .......................................................................................................................... ii  
ABSTRACT ....................................................................................................................................... iii  
ACKNOWLEDGEMENTS .................................................................................................................. iv  
TABLE OF CONTENTS ..................................................................................................................... v  
LIST OF FIGURES ........................................................................................................................... viii  
LIST OF TABLES ............................................................................................................................. xi  
LIST OF ABBREVIATIONS ............................................................................................................... xii  

## CHAPTER 1: INTRODUCTION ................................................................................................. 1  
1.1 Introduction and Background Information ........................................................................... 1  
1.2 Problem Statement .................................................................................................................. 3  
1.3 Purpose of the Study ............................................................................................................... 4  
1.4 Research Questions ............................................................................................................... 4  
1.5 Significance of the Study ....................................................................................................... 5  
1.6 Research Methodology ......................................................................................................... 5  
1.7 Scope and Limitations of the Study ....................................................................................... 6  
1.8 Definitions of Key Terms ..................................................................................................... 7  
1.9 Chapter Outline ..................................................................................................................... 7  

## CHAPTER 2: LITERATURE REVIEW ..................................................................................... 9  
2.1 Introduction ............................................................................................................................ 9  
2.2 Geography and GIS ............................................................................................................... 9  
2.3 Mobile GIS ............................................................................................................................ 11  
2.4 Characteristics of Mobile GIS ............................................................................................ 11  
2.5 Mobile GIS and Fieldwork .................................................................................................. 13  
2.6 Geotechnologies in GIS Education ....................................................................................... 14  
2.7 Mobile GIS Case Studies in Education .............................................................................. 15  
2.8 Mobile GIS Challenges ....................................................................................................... 17  
2.9 GIS in the Secondary School Geography Curriculum in South Africa ............................ 17  
2.10 The Application of Mobile GIS in Tembisa Secondary Schools ................................... 19  
2.11 Conclusion ......................................................................................................................... 20  

## CHAPTER 3: RESEARCH METHODOLOGY ......................................................................... 21  
3.1 Introduction ......................................................................................................................... 21  
3.2 Research Design .................................................................................................................. 21
3.3 Methods

3.3.1 Participants

3.3.2 Instrument for data collection

3.3.3 Data collection

3.3.4 Data analysis

3.4 Ethical Consideration

3.5 Conclusion

CHAPTER 4: DATA PRESENTATION, ANALYSIS, AND INTERPRETATION

4.1 Introduction

4.2 Part 1: Mobile GIS Exercise

4.2.1 Data on the ArcGIS Online platform

4.2.2 Data on the ArcGIS Desktop platform

4.2.3 Spatial data collected by the learners

4.2.4 Examples of captured spatial features with photos

4.2.5 Breakdown of Spatial Data Collected per School

4.3 Part 2: Questionnaire Analysis

4.3.1 Gender of participants

4.3.2 Access to a computer at school

4.3.3 Familiarity with GIS

4.3.4 Mapwork in the classroom

4.3.5 Mapwork frequency

4.3.6 Previous experience with any mobile device in fieldwork

4.3.7 Mobile GIS relevance to learners

4.3.8 Problems experienced with mobile GIS

4.3.9 Application of classroom knowledge to mobile GIS exercise

4.3.10 Time taken to complete the exercise

4.3.11 Attitude towards mobile GIS

4.3.12 Mobile GIS exercises to assist in learning more about GIS

4.3.13 Mobile GIS exercises in a geography lesson

4.3.14 Proposed frequency of mobile GIS exercises

4.3.15 Any other comments regarding mobile GIS

4.4 Summary
CHAPTER 5: SUMMARY OF THE MAJOR FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction .................................................................................................................. 66
5.2 Summary of the Findings ............................................................................................ 66
5.3 Conclusions ................................................................................................................ 67
5.4 Recommendations .................................................................................................... 68
5.5 Suggestions for Future Research .............................................................................. 69

REFERENCES .................................................................................................................... 70

APPENDIX A: DATA PREPARATION FOR MOBILE GIS EXERCISE ......................... 77
APPENDIX B: MOBILE GIS EXERCISE ......................................................................... 92
APPENDIX C: MOBILE GIS MANUAL ........................................................................... 93
APPENDIX D: QUESTIONNAIRE ..................................................................................... 99
APPENDIX E: STUDY PERMISSION .............................................................................. 103
LIST OF FIGURES

Figure 1: Key elements in mobile GIS (Li and Brimicombe, 2013) ................................................. 12
Figure 2: Blackview BV6000 mobile phone with mobile GIS exercise map, Collector for ArcGIS, features for collection .................................................................................................................. 23
Figure 3: Collected data displayed in the ArcGIS Online platform .............................................. 27
Figure 4: The ArcGIS Desktop option for viewing data ............................................................... 28
Figure 5: Presentation of data in ArcMap for further analysis ...................................................... 28
Figure 6: ArcGIS_Collector and ArcGISApp folders on the handheld device ......................... 29
Figure 7: ArcGIS Attachments folder on the mobile GIS handheld device .......................... 29
Figure 8: Example of a feature taken in School A ........................................................................ 32
Figure 9: Example of a feature taken in School B ........................................................................ 32
Figure 10: Example of a feature taken in School C ................................................................. 33
Figure 11: Example of a feature taken in School D ........................................................................ 33
Figure 12: Example of a feature taken in School E ........................................................................ 34
Figure 13: Overview of School A (source: City of Ekurhuleni 2018 imagery) ......................... 34
Figure 14: All features collected in School A ................................................................................ 35
Figure 15: School A point features ............................................................................................. 35
Figure 16: School A line features ............................................................................................... 36
Figure 17: School A polygon features ....................................................................................... 37
Figure 18: School B premises (source: City of Ekurhuleni 2018 imagery) ............................. 38
Figure 19: All features captured in School B ............................................................................... 39
Figure 20: School B point features ............................................................................................. 39
Figure 21: School B line features ............................................................................................... 40
Figure 22: School B polygon features ....................................................................................... 41
Figure 23: School C premises (source: City of Ekurhuleni 2018 imagery) ......................... 42
Figure 24: All features captured in School C ............................................................................... 43
Figure 25: School C point features ............................................................................................. 43
Figure 26: School C line features ............................................................................................... 44
Figure 27: School C polygon features ....................................................................................... 45
Figure 28: School D layout (source: City of Ekurhuleni 2018 imagery) ................................ 46
Figure 29: All features captured in School D ............................................................................... 47
Figure 30: School D point features ............................................................................................. 47
Figure 31: School D line features ............................................................................................... 48
Figure 32: School D polygon features ............................................................................. 49
Figure 33: School E layout (source: City of Ekurhuleni 2018 imagery) ....................... 50
Figure 34: All features captured in School E ................................................................. 51
Figure 35: School E point features ................................................................................ 51
Figure 36: School E line features .................................................................................. 52
Figure 37: School E polygon features ........................................................................... 53
Figure 38: Gender of the participants ........................................................................... 54
Figure 39: Access to a computer .................................................................................... 55
Figure 40: Familiarity with GIS ...................................................................................... 56
Figure 41: Mapwork in the classroom ............................................................................ 56
Figure 42: Previous experience with any mobile device in fieldwork ......................... 57
Figure 43: Mobile GIS relevance to learners .................................................................. 58
Figure 44: Application of classroom knowledge to mobile GIS exercise ..................... 59
Figure 45: Time taken to complete the exercise .............................................................. 60
Figure 46: Attitude towards mobile GIS ........................................................................ 60
Figure 47: Mobile GIS exercises in a geography lesson ................................................ 61
Figure 48: Proposed frequency of mobile GIS exercises ............................................... 62
Figure 49: MobileGISProject ......................................................................................... 77
Figure 50: Creating domains ......................................................................................... 77
Figure 51: Polygon feature class ................................................................................... 78
Figure 52: Polygon feature class coordinate system ..................................................... 78
Figure 53: Polygon feature coordinate system XY tolerance ........................................ 79
Figure 54: Polygon database storage configuration ..................................................... 79
Figure 55: Polygon feature class fields .......................................................................... 80
Figure 56: Line feature class ........................................................................................ 80
Figure 57: Line feature class coordinate system ............................................................. 81
Figure 58: Line feature coordinate system XY tolerance ............................................... 81
Figure 59: Line database storage configuration ............................................................. 82
Figure 60: Line feature class fields ................................................................................ 82
Figure 61: Point feature class field ............................................................................... 83
Figure 62: Point feature coordinate system ................................................................. 83
Figure 63: Line feature coordinate system XY tolerance ............................................... 84
Figure 64: Point database storage configuration ............................................................ 84
Figure 65: Point feature class fields ................................................................................ 85
Figure 66: Creating attachments ................................................................. 85
Figure 67: Publishing the mobile GIS project ............................................. 86
Figure 68: Selecting an existing ArcGIS Online connection ................................. 86
Figure 69: Publishing MobileGIS with feature access capabilities ....................... 87
Figure 70: Enabling all operations on MobileGIS ............................................ 87
Figure 71: Providing MobileGIS tags and description ....................................... 87
Figure 72: Successfully publishing the service on ArcGIS Online ......................... 88
Figure 73: Service on ArcGIS Online ............................................................. 88
Figure 74: Editable features on ArcGIS Online .............................................. 89
Figure 75: Mobile GIS Exercise map, features to be captured and attributes ............ 89
Figure 76: Captured data on ArcGIS Online .................................................. 90
Figure 77: Captured data on ArcGIS Online to be opened in ArcMap .................... 90
Figure 78: Establish connection with ArcGIS Online ........................................ 91
Figure 79: Captured data opened in ArcMap ................................................ 91
LIST OF TABLES

Table 1: Attributes of point features................................................................. 30
Table 2: Attributes of line features...................................................................... 31
Table 3: Attributes of polygon features............................................................. 31
Table 4: School A point attributes..................................................................... 36
Table 5: School A line attributes....................................................................... 37
Table 6: School A polygon attributes................................................................ 38
Table 7: School B point attributes..................................................................... 40
Table 8: School B line attributes....................................................................... 41
Table 9: School B polygon attributes............................................................... 42
Table 10: School C point attributes................................................................. 44
Table 11: School C line attributes.................................................................... 45
Table 12: School C polygon attributes............................................................ 46
Table 13: School D point attributes................................................................. 48
Table 14: School D line attributes.................................................................... 49
Table 15: School D polygon attributes............................................................ 50
Table 16: School E point attributes................................................................. 52
Table 17: School E line attributes.................................................................... 53
Table 18: School E polygon attributes............................................................ 54
Table 19: Problems experienced with mobile GIS.......................................... 58
### LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>CAPS</td>
<td>Curriculum and Assessment Policy Statement</td>
</tr>
<tr>
<td>ESRI</td>
<td>Environmental Systems Research Institute</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>ICT</td>
<td>Information Communication Technology</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
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CHAPTER 1: INTRODUCTION

1.1 Introduction and Background Information

In South Africa, geographic information systems (GIS) are used at all levels of government and in many sectors of society (Macdevette et al., 2005). According to Kerski et al. (2013), countries such as China, Finland, India, Norway, South Africa, Taiwan, Turkey, and the United Kingdom have included GIS in their national educational curricula. In South Africa, GIS was introduced in phases between 2006 and 2008 in the geography curriculum of secondary schools as found in Breetzke et al. (2011).

In the South African Curriculum and Assessment Policy Statement (CAPS), geography is defined as the study of human and physical environments that combines topics related to physical and human processes over space and time. Amongst many geography aims for grade 11, other than explaining and interpreting physical and human geographical processes, geography also seeks to promote the use of technologies, such as information communication technology (ICT) and GIS. Geography as a study also aims to develop geographical skills and promote the asking of geographical questions relating to physical and human processes and location (Department of Basic Education, 2011).

The geography content topics for grade 11 comprise topics including the atmosphere, geographical skills and techniques, geomorphology, development geography, resources, and sustainability. Geography skills and techniques are taught in all four terms and particularly focus on mapwork skills, atlases, topographic maps, aerial photographs, orthophoto maps, and GIS. GIS tackles topics such as spatially referenced data and different types of data, such as line, point, area, attribute, raster and vector data (Department of Basic Education, 2011).

Looking at the CAPS document, one may ask how can GIS be applied to achieve these aims? Many researchers have investigated different applications of GIS in the classroom. In the study conducted by Demirci (2011), it is revealed that the application of a GIS-based exercise in a classroom with only one teacher and one computer can be an effective teaching and learning method. The study further reveals that a GIS-based exercise is helpful for learners to learn about GIS to some extent even if it is applied in a classroom setting with only a single computer. At the same time, students are introduced to aspects of GIS without them having to engage fully with the software themselves. However, the South African context is different. Breetzke et al. (2011) highlighted some GIS implementation challenges, including money, support and time that made GIS implementations in the classroom unsuccessful, which resulted in their investigation of how paper-based GIS could be applied in the classroom to minimise these challenges.
In their research, Komlenovics et al. (2013) found that in almost all countries where GIS was introduced in secondary schools, there were some differences in the way it was used in the teaching process. Geography teachers were expected to not only use digital maps, images and Internet sources, but also to include certain forms of creative work and advanced options within this tool. This led to GIS being viewed as a teaching aid in the context of interactivity in geography lessons.

There has been an increase in the use of handheld devices such as personal digital assistants (PDAs) and tablets in the education space (Lawrence and Schleicher, 2010). According to Al-Emran and Shaalan (2015), using technologies in the educational environment helps to deliver more teaching and learning capabilities to students in a timely fashion; therefore, making teaching and learning successful. Lawrence and Schleicher (2010) explain further that this has led to innovations such as global positioning system (GPS) devices finding their way into the professional environment and are being used in the classroom as well.

Lawrence and Schleicher (2010) ask several questions, including if these devices provide for teaching and fieldwork when used with GIS software, or if they are new geospatial technology substitutes for compasses, maps, and other supplements of geographic inquiry. These questions are answered by Kerski (2011) who maintains that GIS, together with remote sensing and GPS, makes up geotechnologies, which help people make everyday decisions and plan more effectively and efficiently. Therefore, students who use these geotechnologies demonstrate not only the geographic inquiry process of asking geographic questions, but also gaining the opportunity to collect geographic data, analyse geographic information and take appropriate decisions based on geographic knowledge. In line of Kerski’s (2011) analysis, one also has to look at the study of Peirce (2016) that introduced students to mobile GIS technologies such as Google Earth and Collector for ArcGIS. Students had the opportunity to experience data collection with mobile GIS technology first-hand, while also partaking in discussions with one other about technology integration. Furthermore, they were given the opportunity to collect their own data and link their practical field experiences with the theory learnt in the lecture.

These days, students are more willing to learn about technology than teachers (Artvinli, 2010). Focusing particularly on geographical skills and techniques in the CAPS document, the study is expected to contribute by investigating the practicality of applying mobile GIS in schools. Learners are growing up in a technologically advanced world; they have already been exposed to smartphones that are geo-enabled. As Cheung and Hew (2009) state, mobile handheld devices differ from other mobile tools such as laptops because they are light enough to fit in one hand. It is envisaged that learners will have fun while using mobile GIS and that they will gain many geographical skills by infusing theory with the practicality of GIS in the real world.
1.2 Problem Statement

The literature reveals that GIS is applied in schools using different methods. Some of these methods include electronic mapping using GIS desktop software and Internet-based mapping methods which are applied in geography lessons as stated in Demirci (2008) and Bednarz (2004). Fleming (2015) states that even though the incorporation of GIS in the South African educational syllabus over the past decade has gained attention amongst academics and the industry, there are still challenges. These challenges include resource shortages and support concerning strengthening its application as a subject in the educational syllabus of secondary schools in South Africa. In their study, Fleischmann and Van der Westhuizen (2017) also highlight these challenges; however, they do maintain that some South African schools possess computer and/or projector facilities, which could make it possible to include GIS instruction in the classroom setting.

The inequalities between the rich and the poor in South African education become more apparent in the use of information technology (IT), especially in the implementation of geospatial technology in geography classrooms (Innes, 2012). An effort to minimise the challenges led to the investigation of using paper-based GIS. In most South African government schools, GIS theory is taught without using GIS tools. Learners are taken through the GIS concepts in grade 11, but they cannot apply these concepts practically using the software because of the challenges previously mentioned.

The literature suggests that mobile GIS has been widely explored in the education sector in Europe and America. The study conducted by Cilliers et al. (2013) found that in South Africa, GIS is used in many disciplines as an applied research technique; however, not much research has been conducted in the fields of mobile GIS and enterprise GIS.

"Mobile GIS is an integrated technological framework for the access of geospatial data and location-based services through mobile devices, such as Pocket PCs, Personal Digital Assistants (PDA), or smart cellular phones" (Tsou, 2004). Armstrong and Bennett (2005) also highlight the four key technologies that enable mobile computing in geographic education, namely, GPS, GIS, wireless communication, and handheld and tablet computers.

By conducting the study, the researcher wants to establish if mobile GIS can assist learners in learning GIS effectively as part of the geography subject. It should be noted that learners are now getting the opportunity to use mobile devices as a learning platform for different subjects, especially geography, which helps to build their spatial thinking skills (Kolvoord et al., 2017). Therefore, it is envisaged that this study will investigate the application of mobile GIS in schools, which will, in turn, strengthen the application of GIS in geography lessons in schools.
Through informal observations by the researcher and conversations with geography teachers, it was noted that mobile GIS is not utilised in schools when delivering geography lessons. The researcher understands that the mobile GIS used in this study does not offer all of the analytical capabilities that other desktop GIS software offers. However, the researcher takes this as an opportunity that could enable learners to explore another GIS application in the school environment, which prompted the researcher to investigate if mobile GIS is applicable in the geography lesson in grade 11. Since the learners were introduced to GIS in grade 10, the expectation is that they would be able to apply theoretical knowledge/concepts acquired in the previous and current grades in this study.

1.3 Purpose of the Study

Previous researchers have conducted intensive studies on the application of GIS in schools, which include paper-based GIS, a GIS-based exercise in a classroom with only one teacher and one computer, and GIS lessons offered through GPS devices and mobile smartphones. Therefore, the purpose of this study is to investigate the application of mobile GIS in grade 11. This will be achieved by developing a field-based learning exercise (fieldwork), which will give learners the opportunity to capture vector data within their school premises using mobile GIS.

The study is guided by the following objectives:

- To introduce mobile GIS in Tembisa secondary schools.
- To create a mobile GIS exercise for grade 11 geography learners to capture spatial data.
- To assess if learners can apply the theoretical GIS knowledge practically outside the classroom.
- To determine the relevance of geography learners using mobile GIS.
- To establish the challenges and opportunities of using mobile GIS in schools.

1.4 Research Questions

Five research questions were developed to guide this investigation and to address the purpose and underlying objectives:

1. Can learners use mobile GIS?
2. Can the learners identify geographic features within their school premises and capture these features in a spatial data format using mobile GIS?
3. Is mobile GIS relevant to geography learners?
4. Can mobile GIS assist learners in enhancing their GIS knowledge?
5. What are the major challenges and opportunities associated with using mobile GIS in secondary school education?
1.5 Significance of the Study

An investigation of the application of GIS, particularly of mobile GIS in Tembisa secondary schools, is important for several reasons. In studies conducted in South Africa, paper-based and computerised GIS methods have been explored and implemented in classrooms; however, not much research has been conducted on mobile GIS or its implementation in schools. Most schools focus on mapwork skills, including topographic maps, aerial photographs, and orthophoto maps.

When it comes to GIS, learners are taught the concepts, but experience the challenges highlighted before. Since geographical fieldwork has become reliant on mobile technology, Hsu and Chen (2010) highlight that it is important to determine if learners can apply theoretical GIS outside the classroom using mobile GIS. Armstrong and Bennet (2005) indicate that fieldwork plays an essential role in GIS education because students can collect raw data by themselves, which provides an opportunity to teach geospatial skills and technological theories.

For this study, levels of GIS skills will be studied amongst the learners. Johansson (2006) refers to different levels of GIS skills starting with the basic level where learners are able to extract practical examples of spatial data from their surroundings. At this level, they also comprehend GIS data as a combination of location and attributes. This study will add another component mentioned by Johansson (2006) that learners should know how to use mobile GIS services and understand the principles thereof.

It is also important to establish whether mobile GIS can enhance learners’ GIS knowledge. As Martin and Ertzberger (2013) pointed out, it is easier to do activities using mobile devices as they can be used in any context, which will assist in enhancing the learning experience. These activities can assist students doing fieldwork by enabling them to obtain different kinds of information from their location, which can strengthen the link between theoretical and fieldwork knowledge. These reasons will result in determining if mobile GIS can be applied effectively in the geography lesson.

Hsu and Chen (2010) summed it up by stating that without fieldwork, the understanding of geography would be incomplete; perhaps one could say without the application of mobile GIS, the understanding of GIS in the classroom would be incomplete.

1.6 Research Methodology

The University of Salzburg: Geoinformatics Department, Gauteng Department of Education, and Ekurhuleni Northern District office granted permission to the researcher to conduct the study. Five Tembisa secondary schools that offer geography participated in the study. A total number of 82 learners from these schools participated in the study. Non-probability sampling, particularly, purposive or judgmental sampling,
was used to select the participants and the sample for the study. Data collection was conducted over a period of one month towards the end of the third term.

The study used a quantitative and experimental approach. An experimental approach was applied by the learners in terms of collecting new spatial data sets within their school premises using mobile GIS. The learners used Blackview BV6000 mobile devices preloaded with Collector for ArcGIS software. This software was chosen because it can generate points, lines, and polygons, and is freely available on Google Play. The ability to collect data in a coordinated, organised way through mobile applications such as ESRI Collector for ArcGIS, Survey123 for ArcGIS, or ESRI GeoForm improves and increases the opportunities for learners to gather accurate data in different fields (Kolvoord et al., 2017).

Mobile GIS manuals were provided to assist the learners during the mobile GIS exercise. They were tasked with identifying and capturing geographic features as points, lines and polygons within their school premises. Based on the knowledge that they already had, learners were expected to capture features such as school buildings, taps, water tanks, sports facilities, vegetable gardens, cell phone masts, trees, pavements, and any other geographic features within their school premises. They had to provide the description of these features and take photos of them if necessary. The GIS data collected by the students was synchronised in the ArcGIS Online platform, and downloaded and analysed in the ArcGIS Desktop platform.

A quantitative approach was used in the questionnaire part of the study, which the learners answered individually. Learners provided answers regarding the mobile GIS exercise, which provided answers to the research questions. Microsoft™ Excel was used in terms of coding, data entry and analysing the data and chart displays.

1.7 Scope and Limitations of the Study

The researcher approached six secondary schools and obtained permission from five schools to conduct the study. Only grade 11 learners studying geography in the 2018 academic year participated in the study. The study only focused on the use of mobile GIS within this group of learners. The scope of this research was limited to mobile GIS and its application in the secondary school setting. The researcher was aware of other GIS software packages; however, the software used for data collection was Collector for ArcGIS since the rest of the analysis was performed in the ArcGIS environment. The other mobile GIS applications were not covered in this study as it is beyond its scope.

The study was limited to only the premises of each school. The study only dealt with data acquisition/collection by the learners. Many studies indicate the lack of resources in schools (such as computers and GIS software); therefore, data manipulation, data analysis, and presentation by the learners will not be included due to lack of these resources where these processes could be performed.
1.8 Definitions of Key Terms

GIS – A set of integrated software programs designed to store, retrieve, manipulate, analyse and display geographical data. Information concerning people, places and the environment (Demirci, 2008).

Learner- “any person receiving education or obliged to receive basic education in terms of the South African Schools Act” (Republic of South Africa. South African Schools Act, 1996). A learner can also be a pupil or a student at any early learning place, school, further education and training institution or adult learning centre (South African Council for Educators, n.d.).

Mobile GIS – The extension of GIS technology from the office into the field. Mobile GIS incorporates mobile devices, GPS and wireless communications for Internet GIS access. It allows fieldworkers to capture, store, update, manipulate, analyse, and display geographic information (ESRI, n.d.). “An integrated technological framework for the access of geospatial data and location-based services through mobile devices, such as Pocket PCs, Personal Digital Assistants (PDA), or smart cellular phones” (Tsou, 2004).

Mobile device – “A portable, wireless computing device that is small enough to be used while held in the hand; a handheld” (Dictionary.com, n.d.).

GPS – Broda and Baxter (2003) described a GPS as a radio navigation system that allows users to determine accurate location anywhere in the world. GPS devices have GIS functionality built in; they are primarily used for data collection.

Mobile application/app – “Is a type of application software designed to run on a mobile device” (Technopedia, n.d.).

Student- “Is a scholar, a learner, especially one who attends a school” (Merriam-Webster, n.d.).

1.9 Chapter Outline

This research study is presented in five chapters. A brief outline of the chapters follows:

Chapter 1 gave the background information, research problem, aims and objectives, research questions, the significance of the study, chapter breakdown and key concepts.

Chapter 2 provides a review of the literature related to the study of the application of GIS in schools.

Chapter 3 deals with research methodology by highlighting the research design, instruments of data collection, and tools for data analysis.
Chapter 4 includes the data analysis and presentation of results. Data is analysed and presented according to the objectives of the study. Research findings are also discussed in this chapter.

Chapter 5 concludes and summarises the study, and makes recommendations arising from the research.

The reference list and a full set of appendices are also presented in the study.
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, the relevant literature that assisted in shaping this study is reviewed. The purpose of this study is to investigate the application of mobile GIS in grade 11. GIS is mostly taught as part of the geography subject. Therefore, it is important to first define geography and GIS, which will lead to a discussion of how these two are related. The discussion then moves on to mobile GIS so as to understand how it fits in with GIS.

It is also important to highlight the relationship between mobile GIS and fieldwork as mobile GIS operates on the outdoor field environment. Since the study focuses on the education sector, geotechnologies in GIS education are briefly discussed. This takes the discussion to review mobile GIS case studies in education. Towards the end of this chapter, the South African Secondary Geography Curriculum is discussed briefly, the current status regarding the application of GIS is highlighted, and the gaps that can be addressed to enhance the learning and understanding of geography in South African schools are identified. Having addressed all these matters, the interventions that can be applied in terms of mobile GIS in Tembisa secondary schools that teach geography as a subject in grade 11 are briefly highlighted.

2.2 Geography and GIS

Geography is a multifaceted discipline that collects data, which ranges from physical to human aspects, and has the ability to assign relationships and examine them without limitations (Murayama, 2000). Dobson (2008) regarded geography as a spatial way of thinking, a science with unique methods and tools, and a body of knowledge about places; it is about understanding people and places, and understanding how they operate. Furthermore, geography is about understanding spatial distributions and interpreting what they mean. Geography as a subject uses numerous tools and techniques, which are summed up as geographic skills. These skills are used to recognise and explore patterns, processes and relationships in a geographic space (Koutsopoulos, 2010).

Murayama (2000) maintained that geography contributes to methods for acquiring and compiling spatial data because it is a discipline of fieldwork. Its practitioners have a good ability to use interviews, observations, surveys and questionnaires to collect primary data efficiently. Probably the best manner of using geographic data collected in the field (primary data) is developing a way of processing the data in the field and effectively transforming it into spatial data. In this regard, geographers play an essential role in the use of mobile GIS linked with GPS.

“GIS is a computer system designed to collect, store, manage, retrieve, manipulate, analyze, and visualize geographic or spatial data” (Liu and Zhu, 2008). Worboys and
Duckham (2004) described GIS as a computer-based information system that enables the capturing, modelling, storage, retrieval, sharing, manipulation, analysis and representation of spatially referenced data. GIS operates on personal computers (PCs), notebooks, portable PDAs, tablet PCs or handheld GIS/GPS devices (Heywood et al., 2006). In the technological framework, UNEP/GRID-Warsaw Centre (2011) described GIS as a combination of elements of remote sensing and photo interpretation, computer cartography, computer systems supporting the design and planning, databases and monitoring systems functioning in the ICT environment. GIS is used as an important technology that enables students to study their local environment where they can collect data themselves, and use existing data sets as well as other data gathering and analysis tools (Bednarz, 2004).

The relationship between geography and GIS exists because, as Pickles (1995) maintained, GIS provides an information system platform within which virtually all geography can be performed. In GIS, the reality is represented as geographical features according to location and attributes (statistical and non-statistical). However, the geographical location is deemed more important than its attributes (Maguire, 1991). This leads to a conclusion that GIS is a graphical representation of geography and the best way to teach GIS is through the field of geography (Murayama, 2000). The same view is shared by Ida and Yuda (2012): geography is one subject area where GIS can be applied effectively. This is evident in Australian schools where GIS technology is usually dominated by geography departments (Dascombe, 2006). Audet and Paris (1997) also found that while applications of GIS were found in many subject areas, the most common was that it can be used as a tool to enhance learning in geography and environmental science courses.

Globally, a move has been taken to include GIS in school curricula because of its positive impact on geography teaching (Fleischmann and Van der Westhuizen, 2017). This extensive use of GIS technology in subjects at high schools, colleges, and universities has become more popular, which has rendered GIS more significant for academic learning and teaching (Chuang, 2015). Milson and Kerski (2012) found that secondary educators are more likely to teach using GIS than community colleges. This can be seen in the way commercialised professional GIS software packages, such as ArcView, IDRIRI, and SPANS, have played a major role in the development of the GIS resources to support the geography syllabus (Liu and Zhu, 2008). The same applies in Australia where ArcView, MapInfo and Intergraph software programs are used in schools (Dascombe, 2006).

The world has seen a dissemination of spatial information technologies, which include GIS, low-cost GPS, remote sensing image analysis software, open access to data via the Internet, and cost decrease of computer hardware (International Institute for Environment and Development, 2009). In his study, Crabb (2001) highlighted the opportunity to use spatial information technologies to learn geographic concepts, skills, and applications in the classroom such as image processing software, GPS and
GIS, which have already been recognised by geography curriculum specialists for their potential to enhance student acquisition of geographic skills and knowledge.

2.3 Mobile GIS

“Wireless technology provides enormous potential for the creation and use of geoinformation on-the-move.” (Donert, 2007)

Kingston et al. (2012) defined mobile technology as handheld computers, usually with GPS capability (e.g. PDAs and smartphones). They further stated that mobile GIS is a product that developed from the merging of wireless mobile technologies, GIS and GPS, offering users real-time access while on the move using devices that are location enabled. Mobile GIS utilises wireless technologies that enable a real-time connection, which makes it easier for mobile devices to synchronise their local data with the database on the GIS server. As a result, these features make mobile GIS not to be a stand-alone GIS (Li and Brimicombe, 2013).

Tsou (2004) stated that positioning systems, mobile GPS receivers, mobile GIS software, data synchronisation/wireless communication components, geospatial data, and GIS content servers are all components of mobile GIS. Mobile GIS can be held and used anytime and everywhere; it has a small screen and can be connected to the Internet or other device/networks, and it also works in an offline mode (Eleiche, 2011). Li et al. (2002) stated that mobile GIS works with no geographic moving object in a physical space, a relationship between moving object and geographic entity, as well as a moving feature between another moving feature.

According to Li (2007), spatial information transmission is a key technological requirement for mobile GIS. By using wireless communication, the connection between mobile devices and spatial servers is enabled. GIS software for mobile mapping supports the display of vector and raster data and allows the user to edit and query the attribute data associated with spatial features. It also allows the user to download links to photographs, documents, and other images with wireless access to the Internet (Maantay and Ziegler, 2006).

2.4 Characteristics of Mobile GIS

Li (2007) listed the characteristics of mobile GIS as:

- **Mobility.** It can operate on a variety of mobile terminals that offer mobile information services to users through the interaction of wireless communication and remote servers, which makes geographic information always available for field personnel who are on the move.
- **Dynamic and operating in real time.** As a service system, mobile GIS responds to users’ requirements and provides live and current information.
- **Supports applications** with information that relates to the geographic position.
- **Depends on location information.** It requires knowledge of the real-time location of users.
- **Diverse mobile terminal technologies.** It can operate on mobile computers, PDAs, mobile telephones, beep pagers, and vehicle terminal devices.

Armstrong and Bennett (2005) described mobile GIS as comprising four technologies:

- GPS to provide location information.
- GIS software that provides data about location details.
- Wireless communication to provide access to information needed to interpret data and processes.
- Handheld and tablet computers that host the GPS, GIS and wireless communication in a single mobile unit.

Li and Brimicombe (2013) focused on GIS servers; wireless mobile telecommunication networks (connectivity); mobile handheld devices (such as smartphones); location awareness technology; and gateway services as the key elements of mobile GIS as indicated in Figure 1.

Tsou and Kim (2010) stated that the architecture of mobile GIS is similar to Internet GIS because it follows the client/server architecture model as found in traditional Internet GIS applications. The client-side mobile GIS component is the end-user hardware device that displays maps or provides analytical results of GIS operations. The server-side component provides geospatial data and performs GIS operations based on a request from the client-side components. The client communicates with the server through wired cable connections or wireless communications for data exchanges and services to enable comprehensive mobile GIS.

![Figure 1: Key elements in mobile GIS (Li and Brimicombe, 2013)](image-url)
Most mobile GIS applications and application programming interfaces (APIs) for smartphones are built on three main mobile operating systems, namely, Google’s Android, Microsoft’s Phone 7, and Apple’s iOS, and some are developed on BlackBerry smartphones. These applications have GIS software functionalities such as accessing maps and data, and collecting location data in real time. ESRI developed ArcGIS Apps for smartphones, which allows users to navigate maps, collect and report data, and perform GIS analysis via a smartphone. Other applications have been developed on the open source platform (Li and Brimicombe, 2013).

2.5 Mobile GIS and Fieldwork

“The most natural learning is realized through personal experience. The natural environment is the main source of information for learning activities.” (Zoldosova and Prokop, 2006)

Fieldwork should complement the educational experience of the students, the teaching methods, and the subject (Kent et al., 1997). Fieldwork plays an essential role in GIS education because it exposes students to data collection, which provides an opportunity for teaching geospatial skills and technological theories. Indoor and software-operation courses sometimes limit what students can learn because there is no interaction with the real world (Armstrong and Bennett, 2005). The study conducted by Peacock et al. (2018) found that exposing students to fieldwork assisted them in applying theory to practice.

France and Haigh (2018) described seven methods of fieldwork; one of which is a technologically-enhanced method. This method uses a combination of GIS, GPS and Google Earth, bringing about the ground-truthing of fieldwork, which results in fieldwork conducted through mobile handheld devices. Cheung and Hew (2009) categorised the uses of handheld devices in education under seven categories, namely: multimedia access tool, communication tool, capture tool, representational tool, analytical tool, assessment tool, and task managing tool. These mobile devices can be used in any context to enhance the learning experience, such as assisting students in doing fieldwork by enabling them to obtain different kinds of information from the field, which strengthens the link between theoretical knowledge and fieldwork (Martin and Ertzberger, 2013).

Çepni (2013) stated that GIS enables students to play a more effective role in the learning process because GIS incorporates activities conducted inside and outside the classroom, which contributes to the effectiveness of geography teaching. Outside the classroom, activities are conducted with mobile technologies. France and Haigh (2018) advocated that mobile technologies present opportunities for developing new fieldwork pedagogies that will nullify many past fieldwork strategies. When participating in fieldwork, Favier and Van der Schee (2009) advised on student research projects that combine (quantitative) data collection in the field with data visualisation, manipulation, and analysis in GIS. The authors concluded that when
students learn geography by combining fieldwork with GIS, their research skills get stimulated.

Lambriinos and Asiklari (2014) stated that GIS incorporates fieldwork, which helps learners to organise their thoughts, and increases their critical thinking. They further stated that when GIS is combined with GPS, it provides students with the opportunity to use the environment around the school in order to integrate what they have been taught in the classroom. The GPS collects and stores data, and later transfers this data to a GIS. Data from a GIS can be uploaded to GPS for update and maintenance (Mahbubur et al., 2013). The GPS technology in mobile phones or stand-alone devices has made it appropriate to bring this technology into the classroom as it can be used as an educational technological tool (Cyvin, 2013).

Houtsonen (2006) found that through teaching GIS, students can develop logical thinking and problem-solving abilities. This can be done at a basic level where, amongst other things, students are able to extract practical examples of locational data from their everyday surroundings, and understand the nature of GIS data as combinations of locations and attributes. At an advanced basic level of GIS skills, students should, amongst other things, know how to use mobile GIS services and understand the principles behind them. These different levels are also applied in Milson and Kerski (2012). Physical geography students enrol in an introductory GIS course in a school, such as Piner High School, where they are introduced to GIS and GPS concepts and skills.

Kerski (2017) provided different approaches to teaching primary to adult learners about water quality, including using web mapping tools and fieldwork. He further stated that fieldwork can be conducted with students to collect water quality data. They can use either the Collector for ArcGIS app or the Survey123 app from ESRI to populate the water quality variables on smartphones, which have been prepared with the data collection exercise, and map the locations of the water quality collection points.

2.6 Geotechnologies in GIS Education

Computers, the Internet, and handheld devices, such as smartphones and GIS, have changed opportunities for teaching and learning geography in secondary schools (Demirci et al., 2013). Kerski (2011) also acknowledged that the landscape of GIS in education has improved because of improved Internet bandwidth, faster and less expensive computers, and user-friendly geotechnologies.

The utilisation of mobile applications and devices has recreated the use of geospatial technologies at all levels, including schools. Students are now using mobile devices as a learning platform for a variety of subjects – especially geography to build their spatial thinking skills (Kolvoord et al., 2017). However, it is important to note that it is only those with a good Internet connection, computers, and mobile devices who benefit from using these geotechnologies. When using these technologies, students
only need a smartphone rather than a separate GPS receiver and a digital camera to take GPS-tagged photographs and videos to build rich field-based GIS projects, (Kerski, 2011).

When students use geotechnologies, they demonstrate the geographic inquiry process of asking geographic questions, gathering geographic data, assessing geographic information, and analysing geographic information (Kerski, 2011). These geotechnologies, which include GIS, GPS and remote sensing, enable the acquisition of data and maps through fieldwork (Kerski, 2008). This composition of technologies is also highlighted by Weng and Ling (2007) as comprising GPS, remote sensing, 3D, mobile equipment, web and other information technologies.

2.7 Mobile GIS Case Studies in Education

Mobile devices with apps provide more functions than usual handheld GPS receivers, for example, connectivity with the Internet and other applications, in addition to the standard functions of capturing coordinates and exporting them to a computer (Cyvin, 2013). Tsou and Yanow (2010) stated that smartphones connect GIS with students’ daily lives. The power of GIS in their mobile phones enables them, amongst others, to find destinations and other places of interest on platforms such as Google Maps.

Mobile tablet PCs loaded with scientific visualisation software allow for classes to be taught outside, where field methods are demonstrated and data is collected in real time (Stewart et al., 2011). Neumann and Kutis (2006) conducted a mobile GIS study that introduced students to a new mobile GIS technique while incorporating previously learnt geologic knowledge. In this study, field data was recorded digitally and linked to geographical points on a map using GPS and GIS. Johansson (2006) conducted a study on the ecological state of local rivers. Students collected water quality data from local rivers and used GPS receivers to capture the exact location. This data was later visualised as points on digital maps together with the collected attribute data. Kankaanrinta (2006) involved students in locating paper baskets with GPS for the local municipality.

Kingston et al. (2012) conducted a study with students in the field of hydrology where the emphasis was on using GPS. The exercise involved collecting spatial data in the form of track logs and waypoints for various areas of the university campus using GPS-enabled PDAs. Another component of the exercise incorporated the use of GPS and GIS using ArcPad software to record and map temperature readings in designated areas. Although their paper focused on mapping and climatology applications, they stated that the mobile technologies used in the field exercise enhanced interactivity and opportunity for “learning by doing”, which are considered to be the driving forces behind the enthusiasm and success of the students.

Ida and Yuda (2012) pointed out that if GIS could be used everywhere and connected to a network to allow the input, editing, and processing of data in the field, then moving
data into desktop GIS after fieldwork will not be necessary, hence the introduction of cellular phone GIS. Using cellular phone GIS, students were tasked with collecting data and taking images on land use and mulberry fields. On evaluation, it was found that generally students’ satisfaction with the classes in fieldwork was high. It was reported that a great deal of time can be saved by using cellular phone GIS.

Cyvin (2013) conducted a study that gave students a handheld GPS receiver (Garmin eTrex Legend) and Garmin’s mapping program, called MapSource, which in this study was used as a GIS tool. They were assigned to collect two water samples and to record the route points of the water samples using the GPS. They also had to record new locations for nesting boxes and tree species in a defined forest area. The findings of this study mentioned that all students who participated mastered the use of a GPS receiver within a short time despite only being given a brief introduction on to how to use it, whereafter they had to try to use it on their own. Broda and Baxter (2003) also provided an example of GPS device use. Students used GPS devices to locate points of interest around the school or community, such as certain species of trees, parks and the recreation centre.

France and Haigh (2018) asked how much fieldwork and what kind of fieldwork activities are best for a geography curriculum since fieldwork is a very limited resource in most geography programmes. The answer was provided by Kolvoord et al. (2017) who found that mobile apps improve and increase the opportunities for students to collect data in a coordinated and a systematic way. They noted that it is usually difficult to collect data due to time limits, and equipment and other issues. Kolvoord et al. (2017) advocated using applications such as Esri Collector for ArcGIS. In their study, students used Esri Collector to collect spatially enabled data within school premises during one class period.

In their paper, Pánek and Glass (2018) evaluated their experiences in setting, deploying, and analysing data obtained through Collector for ArcGIS for a mobile GIS exercise conducted by students in Lawrenceville. During this exercise, students collected 122 point features, 28 polygon features, 86 geotagged photos, and one video. Stonier (2015) introduced students to mobile GIS. During this project, students had to capture items such as lighting, plant life, security boxes, vehicles and wildlife within the campus using the downloaded Collector for ArcGIS app on their personal mobile devices. Furthermore, Peirce (2016) introduced her students to mobile GIS technologies, such as Google Earth and Collector for ArcGIS. These students had the opportunity to experience data collection first-hand with mobile GIS technology.

Tsou (2004) highlighted many advantages of using mobile GIS devices for environmental management and habitat monitoring. In his case study, he used Internet map service, a pocket PC loaded with ESRI ArcPad software, and GPS to collect spatial data through a wireless network.
All these case studies support the study by Cyvin (2013) that the developments in integrated GPS functions in mobile phones will make it easier for this technology to be introduced in the future due to many free Internet resources as well as apps being accessible via computers and mobile phones. These developments support the thinking of new educational possibilities such as mobile learning activities, which are facilitated by mobile devices with wireless connectivity or a GPS (Hsu and Chen, 2010).

2.8 Mobile GIS Challenges

Just like any other tool, mobile GIS has its own challenges. Li and Brimicombe (2013) highlighted that mobile GIS will benefit from rapid development in a mobile telecommunication network, and mobile device technologies will bring even faster data transfer speeds, better connectivity, and more advanced devices. However, issues concerning the reliability and consistency of network infrastructure and devices, which mobile GIS relies on to build, implement and deliver applications, should also be considered. Li and Brimicombe (2013) further state that issues relating to the design of the devices (such as screen size and resolution, keyboard/keypad, memory, and optional additional memory) should also be considered for mobile GIS to work optimally. Furthermore, Kingston et al. (2012) observed during their study that some students complained about PDAs being a little awkward to use during the mobile technology exercise, due to their small screens, fonts, and buttons.

The short battery life of smartphones cannot be ignored. GPS for location awareness in a smartphone does not work and may give erroneous results where the signals of three or more satellites are not available (Li and Brimicombe, 2013).

2.9 GIS in the Secondary School Geography Curriculum in South Africa

In South Africa, the Department of Basic Education (2011) defines geography as the study of human and physical environments; a subject that combines topics related to physical and human processes over space and time. One of the geography aims for grades 10 to 12 learners is promoting the use of new technologies, such as ICT and GIS.

According to Kerski et al. (2013), countries such as China, Finland, India, Norway, South Africa, Taiwan, Turkey, and the United Kingdom have included GIS in their national educational curricula. Between 2006 and 2008, GIS was introduced in phases in the South African geography curriculum of secondary schools (Breetzke et al., 2011). GIS, mapwork skills, topographic maps, aerial photos and orthophoto maps, atlases and fieldwork are all grouped together as geographical skills and techniques in the CAPS document for the geography subject. In grade 11, GIS covers areas such as (Department of Basic Education, 2011):
• Spatially referenced data;
• Spatial and spectral resolution;
• Different types of data: line, point, area, and attribute;
• Raster and vector data;
• Applying GIS to climatology, meteorology, and oceanography using satellite images;
• Capturing different types of data from existing maps, photographs, fieldwork or other records on tracing paper.

When one looks at other countries, İncekara (2012) stated that GIS was integrated in Turkey in geography education and adopted in the high school curriculum in 2005. Similarly to South Africa, the emphasis was on geographic skills and applications comprising map skills, IT skills, critical thinking skills, and fieldwork. Combining all these skills makes GIS significant in terms of helping students to learn geography by practising spatial thinking (Bednarz, 2004).

Studies conducted outline some of the challenges found in many countries, including developed countries that prevent the effective use of GIS in geography lessons at secondary school level. These challenges are similar in many countries, and they have channelled numerous studies to find different methods for incorporating GIS in schools (Demirci, 2011). Kerski (2011) highlighted the technological and societal challenges of GIS in secondary school education that have been the subject of many studies. Technological challenges include access to computers with the correct specification for loading appropriate GIS software as well as IT support. Societal issues include the lack of awareness of spatial thinking and analysis, and their importance in education and society. Ida and Yuda (2012) shared a similar observation in their study that the high cost of GIS software makes it a challenge to implement GIS in schools.

The implementation of GIS in South African schools has also been delayed due to the lack of curriculum-orientated reasonably priced GIS software, necessary computer hardware, and teachers’ GIS teaching knowledge (Fleischmann and Van der Westhuizen, 2017). Kerski (2003) pointed out the lack of time to develop GIS-based lessons, little support for training and implementation, and complexity of software as some of the reasons that delay the expansion of GIS in United States education.

Breetzke et al. (2011) reported on numerous challenges concerning the implementation of GIS in South African secondary schools. Sumari et al. (2017) highlighted similar challenges in their study. These challenges included a shortage of resources, and little support from school leadership, school communities and local tertiary institutions, government and the GIS industry. Furthermore, Fleming (2015) observed that even though GIS has been incorporated in the South African educational syllabus over the past decade and has gained attention amongst academics and the industry, there are still challenges such as resource shortages and support concerning strengthening its application as a subject in the educational
syllabus of secondary schools in South Africa. Additionally, the inequalities between the rich and the poor in South African education become more apparent in the use of IT, especially in the implementation of geospatial technology in geography classrooms (Innes, 2012). As a result, it is not possible for GIS to be used in most schools, leading educators to using ‘paper GIS’ as indicated in the Department of Basic Education (2011) CAPS document.

However, a study by Fleischmann and Van der Westhuizen (2017) showed that GIS can be integrated and practised within South African grade 10–12 geography classes where there are computers and projectors. A study conducted by Demirci (2011) revealed that implementing a GIS-based exercise in a classroom with only one teacher and one computer can be an effective teaching and learning method. Some of the implications of the non-implementation of GIS were realised in South Africa. In 2015, the Northern Cape Department of Education discovered that grade 12 learners were not answering exam questions relating to GIS in the Geography Paper 2 of their final exams. After conducting an investigation, the department found that because of a lack of exposure to the practical side of GIS, the learners found the section challenging, as it requires hands-on experience in order to be applied (Position IT, October 2015).

Despite the GIS implementation challenges, Fleischmann and Van der Westhuizen (2017) identified paper-based GIS, QGIS, web-based GIS, and ArcGIS Online as other teaching avenues that could be explored in the South African education context. Online GIS options have eliminated some of these challenges, especially those that are cost related; however, good computers and networks still have to be acquired and maintained (Mitchell et al., 2018).

Demirci (2008) and Bednarz (2004) in their studies found that GIS is applied in geography lessons in electronic mapping using GIS desktop software and Internet-based mapping methods. Similarly, Akinyemi (2015) also found that most teachers in Rwanda used Google Maps, some used ArcGIS, while a few conducted GIS projects relevant to the community with their students. Google Earth is also widely used in classrooms globally as a teaching tool because of its user-friendly interface (Demirci et al., 2013). Allen (2008) advocated the use of virtual globes such as Google Earth in a classroom for, firstly, kick-off tours at the beginning of the class to take students on a short “virtual field trip”; secondly, for on-the-fly inquiry-based investigations; and, lastly, for offline virtual field trips.

2.10 The Application of Mobile GIS in Tembisa Secondary Schools

Many researchers have conducted intensive studies regarding the application of GIS in schools. These studies include using paper-based GIS, doing a GIS-based exercise in a classroom with only one teacher and one computer, and offering GIS lessons through GPS devices and mobile smartphones. Nowadays, students are more eager to learn about technology than teachers (Artvinli, 2010). Therefore, students rather need to be encouraged to learn more about, and see how new GIS techniques are
used than obtaining theoretical knowledge on GIS basics (UNEP/GRID-Warsaw Centre, 2011). In this context, Kingston et al. (2012) maintained that the use of mobile technology will be useful in offering the potential to develop modern mapping skills, which can be applied to real-world applications. This is the new methodology and technology that Kent et al. (1997) referred to that have partially replaced some traditional types of field practice used to gather data on spatial projects, which use portable devices to record and provide instant analysis of project data while still in the field.

Therefore, the purpose of this study is to investigate the application of mobile GIS in grade 11. This will be achieved by developing a field-based learning exercise. The study will use a quantitative and experimental approach. A quantitative approach will be used to determine the level of mobile GIS usage. This will be in a statistical form, which is numerical. The experimental approach will be applied by the learners in terms of collecting new spatial data sets within school premises using mobile GIS. They will use Blackview BV6000 mobile phones preloaded with Collector for ArcGIS software. The software was chosen because the researcher is more familiar with Esri software than other options available. Blackview BV6000 mobile phones were chosen because of their portability and ruggedness. These phones will not be damaged easily by the learners during fieldwork. Furthermore, the phones work seamlessly with ArcGIS mobile applications.

2.11 Conclusion

This chapter established the relationship between geography and GIS. Mobile GIS, its characteristics, opportunities, and challenges were discussed. The challenges that many countries face when it comes to implementing GIS in the classroom were highlighted. The South African Secondary Geography Curriculum was briefly discussed, the current status regarding application of GIS was highlighted, and the gaps that can be addressed to enhance the learning and understanding of geography in South African schools were identified. The literature showed that technology costs have been reduced and that network connectivity has also improved significantly. Therefore, the mobile GIS solution that has been tried and tested in other countries can also be applied in South African schools.
CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents a description of the research methodology that was followed in the investigation of the application of mobile GIS in grade 11. It also describes the research design that was chosen and the reasons for choosing it. The information concerning the participants and how they were sampled is provided. The instruments that were used for data collection and the procedure that was followed to conduct this study are also discussed.

3.2 Research Design

The practical goal of many research studies in social sciences is to solve a specific problem or suggest alternatives (Steinberg and Steinberg, 2006). According to Elwood and Cope (2009), GIS is mainly related to statistical and quantitative spatial analysis. Therefore, a quantitative research methodology was used, which was described by Muijs (2010) and Leung and Shek (2018) as the methodology for gathering numerical data to explain a particular phenomenon. This type of methodology is widely used in educational research.

There are two main types of quantitative research design, namely, experimental and non-experimental research design (Leung and Shek, 2018). This study followed the experimental design, which Muijs (2010) described as a test under controlled conditions that is designed to show a known truth or examine the validity of a hypothesis. In this study, the participants were given a mobile GIS exercise. They used mobile GIS handheld devices to capture geographic features within their school premises in point, line and polygon format. The second part, comprising the questionnaire that was completed by participants regarding the mobile GIS exercise, provided answers to the following research questions:

1. Can learners use mobile GIS?
2. Can learners identify geographic features within their school premises and capture these features in a spatial data format using mobile GIS?
3. Is mobile GIS relevant to geography learners?
4. Can mobile GIS assist learners in enhancing their GIS and geography knowledge?
5. What are the major challenges and opportunities associated with using mobile GIS in secondary school education?

3.3 Methods

3.3.1 Participants

Non-probability sampling, particularly purposive or judgmental sampling, was used to select participants and the sample for the study. This method is appropriate for
selecting a sample on the basis of knowledge of a population, its elements, and the purpose of the study (Babbie, 2013).

Five Tembisa secondary schools offering geography were selected for the study. The schools will be referred to as School A, School B, School C, School D and School E to comply with paragraph 11 of the Gauteng Department of Education research approval letter (Appendix E). This condition states that the names of the schools that participate in the study may not appear in the research report without the written consent of each of these organisations.

A total number of 82 learners from these five schools participated in the study. Twenty participants from each of the following schools took part in the study: School A, School B and School C. School D had ten participants because the grade 11 geography class only consisted of ten learners. School E had 12 participants. All learners who participated in the study were selected by teachers at the respective schools.

The decision of the researcher is a major factor in this type of sampling (Strydom, 2012). The researcher was particularly interested in the views of grade 11 learners as they have been introduced to GIS in grade 10. The researcher felt that the grade 11 learners would be more willing to participate in the study to put into practice what they have already learnt.

3.3.2 Instrument for data collection

3.3.2.1 Mobile GIS

Blackview BV6000

Most mobile GIS applications and APIs for smartphones are built on three main mobile operating systems, namely, Google’s Android, Microsoft’s Phone 7, and Apple’s iOS (Li and Brimicombe, 2013). Therefore, a Blackview BV6000 Android 7.0 smartphone was used. Its key features as listed on the pamphlet are:

- IP68 design
- 4.7" HD 1280 x 720 display
- Gorilla Glass 3
- 4500 mAh battery (1–3 days battery life)
- Octa Core 2.0 GHz central processing unit
- 3 GB RAM
- 32 GB internal memory
- Dual micro sim (open to all networks)
- Android 7.0 Nougat
- Metallic frame, and
- Push-to-talk.
Collector for ArcGIS

Collector for ArcGIS was downloaded to the Blackview BV6000 mobile phones using Google Play. Collector for ArcGIS allows participants to collect vector data such as points, lines, and polygons. For the exercise in this study, a layer was made available within a feature service that contained points, lines and polygons feature classes. Each record captured information regarding the unique ID, geographic location, feature name, description, and the information of the data capturer. After the feature layer was published on ArcGIS Online, the data collection form was configured. The feature service was available and downloaded on the mobile phones through the downloaded Collector for ArcGIS app as indicated in Figure 2. The step-by-step method of how this feature service layer was configured is available in Appendix A.

![Figure 2: Blackview BV6000 mobile phone with mobile GIS exercise map, Collector for ArcGIS, features for collection](image)

3G data bundles (for connectivity with ArcGIS Online)

The distinctive feature of mobile GIS is the ability to combine GPS and ground-truth measurement within GIS applications (Drummond et al., 2006). In this regard, the participants used mobile GIS instruments to demonstrate previous knowledge acquired in the classroom in terms of identifying and capturing geographic features within the school premises. The items identified and captured within the school premises were ground-truthed through this exercise.

3.3.2.2 Questionnaire

Muijs (2010) stated that survey research is the most popular quantitative research design in social sciences. It is usually characterised by collecting data using standard questionnaire forms, which are administered by telephone, face to face, postal pencil-and-paper questionnaires, or web-based and e-mail forms.
The participants completed the questionnaire after using the mobile GIS instruments. The purpose of the questionnaire was to determine their opinion regarding the mobile GIS exercise.

### 3.3.3 Data collection

Data collection was conducted over a period of one month towards the end of the third term. A total of 82 grade 11 learners from five different secondary schools in Tembisa participated in the study. To capture data in Collector for ArcGIS, users need to have an ArcGIS organisational account. Therefore, the researcher’s login details were used on all mobile GIS handheld devices for the purpose of this study.

The participants were given short training on how to use the mobile devices. They received the training manual as reference (see Appendix C). After training, they collected data in pairs as per the instruction in the mobile GIS exercise in Appendix B. Only participants in School D operated the mobile devices individually because the grade 11 geography class only consisted of ten learners. In School E, only two participants were paired because there were 12 learners in total. The participants were able to collect vector data such as points, lines, and polygons, which were synchronised with the mobile GIS feature service hosted on ArcGIS Online.

The exercise only exposed learners to the data collection part of mobile GIS. They were not exposed to the ArcGIS Online platform, data manipulation, data analysis and presentation due to a lack of time and resources as the exercise was supposed to be completed within 60 minutes.

The participants completed the questionnaire (attached as Appendix D) after the mobile GIS exercise. To maintain the anonymity of the participants, they were not asked to provide their names, and the questionnaires were not numbered prior to being issued to them. No personal data of the participants was collected. The questionnaire was not long so as not to exhaust the participants as they responded to the questionnaire immediately after doing the mobile GIS exercise.

### 3.3.4 Data analysis

Data collected in the mobile GIS exercise was analysed using ArcGIS Desktop software. Firstly, it was analysed per school. Thereafter, the data was analysed per feature class whereby by similar features in different schools were allocated the same symbology.

According to Fouché and Bartley (2012), quantitative data in research can be analysed manually or by computer. If the sample is small, some statistical analyses can be performed manually with calculators. Statistics can also be computed with a spreadsheet program such as Microsoft™ Excel. Data collected from the questionnaires was analysed in Microsoft™ Excel, which was used to produce tables and graphs.
3.4 Ethical Consideration

The University of Salzburg: Geoinformatics Department, Gauteng Department of Education, and Ekurhuleni Northern District office granted permission to conduct the study. The school principals were visited and consent forms were left to be completed by the participants and their parents before the study commenced (see Appendix E).

3.5 Conclusion

This chapter outlined how the research was conducted in the investigation of the application of mobile GIS in grade 11, the selection method that was followed to select the participants, the instruments that were used, and the procedure for data collection. The next chapter contains data interpretation, analysis, and presentation of the results.
CHAPTER 4: DATA PRESENTATION, ANALYSIS, AND INTERPRETATION

4.1 Introduction

The previous chapter discussed the methodology and data collection methods used in this study. This chapter presents, analyses and interprets the findings of the investigation of the application of mobile GIS in grade 11. The first part of the findings is based on the data collected through an experimental approach. The learners used mobile GIS to collect geographic features inside their school premises. This data is presented as points, lines, and polygons per school.

The second part of the findings is based on the quantitative approach. Questionnaires were hand-delivered to the participants after the mobile GIS exercise. Data analysed from the questionnaires is presented as percentages, graphs, and tables.

The findings are presented according to the following objectives of the study:

- To introduce mobile GIS in Tembisa secondary schools.
- To create a mobile GIS exercise for grade 11 geography learners to capture spatial data.
- To assess whether learners can apply their theoretical GIS knowledge practically outside the classroom.
- To determine the relevance of using mobile GIS by geography learners.
- To establish the challenges and opportunities of using mobile GIS in schools.

4.2 Part 1: Mobile GIS Exercise

Data collection was conducted over a period of one month towards the end of the third term. The participants were issued with ten Blackview BV6000 mobile phones with data bundles for 3G/4G connection. The mobile phones were also loaded with Collector for ArcGIS software to complete the mobile GIS exercise. Sixty minutes was allocated for this exercise, which was deemed sufficient because a similar study was conducted by Kolvoord et al. (2017). In this study, learners collected vector data using Esri Collector for ArcGIS within school premises during one class period.

Capturing data in Collector for ArcGIS requires users to have an ArcGIS organisational account. Therefore, the researcher’s login details were used on all mobile GIS handheld devices for purposes of this study. The participants were given short training on how to use the mobile devices. They received the training manual as reference (see Appendix C). After training, they did data collection in pairs as per the instruction on the mobile GIS exercise in Appendix B. Only participants in School D operated the mobile devices individually because the grade 11 geography class only consisted of ten learners. In School E, only two participants were paired because there were 12 learners in total.
The participants were able to collect vector data such as points, lines, and polygons, which were synchronised with the mobile GIS feature service hosted on ArcGIS Online. Murayama (2000) maintained that one of the best ways of using geographic data collected in the field (primary data) is to develop a way of processing the data in the field and effectively transforming it into spatial data, such as mobile GIS linked with GPS.

The geographic data collected in the field included 142 points, 112 lines and 110 polygons. The learners also captured 182 pictures linked with features. Similarly, a study conducted by Pánek and Glass (2018), which analysed data obtained through Collector for ArcGIS for the mobile GIS exercise conducted by students in Lawrenceville, found that students collected 122 point features, 28 polygon features, 86 geotagged photos, and one video.

4.2.1 Data on the ArcGIS Online platform

Data was instantly uploaded to the ArcGIS Online platform as participants were collecting it. The data was synchronised using the ArcGIS Online account, which is the platform as indicated in Figure 3 and Figure 4 on which the mobile GIS project was shared. Thereafter, the data was opened and saved in ArcGIS for Desktop for further analysis as indicated in Figure 5. No features were deleted or edited.

![Figure 3: Collected data displayed in the ArcGIS Online platform](image-url)
Data analysis was performed using ArcGIS Desktop. When the data was in the ArcGIS Desktop environment, it was imported into the mobile GIS project file geodatabase. It must be noted that attachments (pictures) with spatial data could not be exported to ArcGIS Desktop. The mobile GIS handheld device saved pictures on its ArcGIS App Attachment folders as shown in Figure 6 and Figure 7.
Data collected by the participants was presented as it was collected. It was then easy to use the Select Features tool to select data per school. Not every feature was accompanied by a photo. The researcher attached photos to corresponding features manually using the Editor method in ArcMap. This was done by identifying the feature in ArcGIS Online, which also displayed the image of that feature. The same photo was associated with the feature on ArcGIS Desktop. A new field, namely, “School” was added in the attribute tables in order to organise data collected by each school.

The simple query method was used as the primary data analysis in this study. According to Maantay and Ziegler (2006), one of the most basic spatial analytical methods in GIS is the simple query, which is also known as a phenomenon-based search. This method is used when searching for a spatial feature or an attribute that meets certain criteria. After the search, the records meeting that criteria are selected, and highlighted on the map and attribute table. The attribute table was further used to count the number of features and to check for duplicates. The aerial photography assisted with checking the duplicated features.
ArcGIS Desktop has two tools for managing duplicate records, namely, Find Identical and Delete Identical. However, only Find Identical was used in this study. The Find Identical tool proved to be ineffective due to the different proximities at which the features were captured, different naming conventions for features, and misspellings of the same features. Another observation was that different features were assigned the same and description, for example, FeatureName: teekay, tree and tree1, Description: tall and green. Therefore, the duplicates were checked manually in the attribute table and data view. Duplicates were also verified using the feature pictures taken by learners. In some instances, five photos of one feature were found. These photos were verified in different mobile GIS devices. All these proved that the features were captured by different learners so they were not to be regarded as duplicates. After this verification exercise, the features were grouped and assigned different symbology for representation on the map.

4.2.3 Spatial data collected by the learners

Table 1, Table 2 and Table 3 show the data that was collected by the learners, who collected 142 point, 112 line, and 111 polygon features. Amongst the point features, there were trees, poles, lights, water tanks, and cell phone towers. In a study conducted by Johansson (2006) that determined the ecological state of local rivers, students collected water quality data from local rivers and used GPS receivers to capture the exact locations. These were later visualised as points on digital maps together with the collected attribute data.

The line features collected by learners consisted of passages and pavements. Polygon features consisted of classrooms, toilets, offices, and parking areas.

*Table 1: Attributes of point features*
Table 2: Attributes of line features

<table>
<thead>
<tr>
<th>No.</th>
<th>FeatureID</th>
<th>FeatureName</th>
<th>Description</th>
<th>CaptureYear</th>
<th>Gender</th>
<th>ShapeArea</th>
<th>Shapely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Road</td>
<td>Main road</td>
<td>2012</td>
<td>Male</td>
<td>894</td>
<td>894</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Walkway</td>
<td>Pedestrian walkway</td>
<td>2013</td>
<td>Female</td>
<td>567</td>
<td>567</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Bicycle path</td>
<td>Path for bicycle riders</td>
<td>2014</td>
<td>Male</td>
<td>234</td>
<td>234</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Cycle track</td>
<td>Track for cyclists</td>
<td>2015</td>
<td>Female</td>
<td>321</td>
<td>321</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Footpath</td>
<td>Path for pedestrians</td>
<td>2016</td>
<td>Male</td>
<td>987</td>
<td>987</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Steps</td>
<td>Stairway</td>
<td>2017</td>
<td>Female</td>
<td>456</td>
<td>456</td>
</tr>
</tbody>
</table>

Table 3: Attributes of polygon features

<table>
<thead>
<tr>
<th>No.</th>
<th>FeatureID</th>
<th>FeatureName</th>
<th>Description</th>
<th>CaptureYear</th>
<th>Gender</th>
<th>ShapeArea</th>
<th>Shapely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Park</td>
<td>Public park</td>
<td>2018</td>
<td>Male</td>
<td>123</td>
<td>123</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Swimming pool</td>
<td>Facility for swimming</td>
<td>2019</td>
<td>Female</td>
<td>456</td>
<td>456</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Beach</td>
<td>Location for sunbathing</td>
<td>2020</td>
<td>Male</td>
<td>789</td>
<td>789</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Pier</td>
<td>Dock for maritime vessels</td>
<td>2021</td>
<td>Female</td>
<td>321</td>
<td>321</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Marina</td>
<td>Terminal for boat storage</td>
<td>2022</td>
<td>Male</td>
<td>567</td>
<td>567</td>
</tr>
</tbody>
</table>

...
4.2.4 Examples of captured spatial features with photos

Figure 8 to Figure 12 display examples of the geographic features in schools captured by learners using mobile GIS.

Figure 8: Example of a feature taken in School A

Figure 9: Example of a feature taken in School B
Figure 10: Example of a feature taken in School C

Figure 11: Example of a feature taken in School D
4.2.5 Breakdown of Spatial Data Collected per School

4.2.5.1 School A

In School A (indicated in Figure 13), twenty learners participated in the mobile GIS data collection exercise. The learners captured 38 point, 22 line, and 21 polygon features, which brought the total number of features captured in this school to 81. These different features can be seen in Figure 14.
In School A, learners collected 38 point features as shown in Figure 15 and Table 4. The features that were collected included trees, a cell phone tower, a JoJo water tank, classrooms, a flag holder, an electric box, a danger box, a water tap, and an emergency water pipe.

Figure 14: All features collected in School A

Point features

In School A, learners collected 38 point features as shown in Figure 15 and Table 4. The features that were collected included trees, a cell phone tower, a JoJo water tank, classrooms, a flag holder, an electric box, a danger box, a water tap, and an emergency water pipe.

Figure 15: School A point features
Line features

Figures 16 and Table 5 indicate the line features that were collected by the participants. These features include pavements, a grass field, a parking lot, a netball court, a school fence, a row of classes, a passage, and a school name board. It must be noted that it is not the norm to capture a row of classes as a line feature; the learners were expected to capture it in polygon format. Table 5 also indicates a feature that was captured with no attributes.
Table 5: School A line attributes

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matric block</td>
<td>Parking lot</td>
<td></td>
</tr>
<tr>
<td>Classroom</td>
<td>Staff room</td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>Toilet</td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>Kitchen</td>
<td></td>
</tr>
<tr>
<td>Electric box</td>
<td>Transformer</td>
<td></td>
</tr>
</tbody>
</table>

Polygon features

Figure 17 and Table 6 indicate 21 polygon features that were collected by the learners within School A’s premises. These features include the matric block, parking lot, staff room, office, classrooms, a JoJo water tank, a transformer, toilets, grass, the kitchen, and an electric box. The learners were expected to capture the JoJo water tank, transformer, and an electric box as points instead of polygons.
4.2.5.2 School B

There were 20 learners who participated in the mobile GIS exercise in School B (shown in Figure 18). They collected 28 point, 21 line, and 20 polygon features as indicated in Figure 19. In total, 69 geographic features were collected.

Figure 18: School B premises (source: City of Ekurhuleni 2018 imagery)
Point features

In School B, the participants captured point features such as trees, poles, water taps, a danger box, a rock, and classrooms (as shown in Figure 20 and Table 7). Table 7 shows that a point feature was captured with no attributes.
Table 7: School B point attributes

Line features

Figure 21 and Table 8 indicate the line features captured by the learners, including lines, passages, a row, stairs, a way, and a dusty road.

Figure 21: School B line features
Table 8: School B line attributes

Polygon features

The polygon features that were collected by the learners in this school are the school's zozo (a shack), library, house, school field, class, teachers' office, parking lot, and a main office (as shown in Figures 22 and Table 9). Figure 22 and Table 9 indicate that a person, bins, living birds and cars were also captured as polygon features; these features are usually captured as points.

Figure 22: School B polygon features
Features collected in School B are similar to features collected by learners in the study conducted by Stonier (2015), who captured items such as lighting, plant life, security boxes, vehicles and wildlife on the campus using the Collector for ArcGIS app in their personal mobile devices.

**4.2.5.3 School C**

20 learners participated in the mobile GIS exercise in School C (indicated in Figure 23). The learners captured 20 point, 23 line, and 21 polygon features as displayed in Figure 24. The total number of features captured was 64.
Point features

Figure 25 and Table 10 indicate the point features that were collected by the participants in School C. These features include palm trees, pine trees, a JoJo water tank, and a water pump.

Figure 24: All features captured in School C

Figure 25: School C point features
Line features

The line features that were collected included pavements, a palm tree, a pathway, a fence, and passages (as indicated in Figure 26 and Table 11). Figure 26 and Table 11 further indicate that some of the participants captured a JoJo tank and a palm tree as line features, which is not the norm as these features are usually captured as points. Table 11 indicates that some features were captured without attributes.
Table 11: School C line attributes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass/lawn</td>
<td>G</td>
<td>Green area</td>
</tr>
<tr>
<td>Classrooms</td>
<td>C</td>
<td>Classrooms</td>
</tr>
<tr>
<td>Bookstore</td>
<td>B</td>
<td>Bookstore</td>
</tr>
<tr>
<td>Office</td>
<td>O</td>
<td>Office</td>
</tr>
<tr>
<td>Hall</td>
<td>H</td>
<td>Hall</td>
</tr>
<tr>
<td>Water area</td>
<td>W</td>
<td>Water area</td>
</tr>
</tbody>
</table>

Polygon features

The polygon features were captured included the grass/lawn, classrooms, bookstore, office, hall, and water area (as indicated in Figure 27 and Table 12). Table 12 further indicates that some of the participants captured the features with incomplete attributes.

Figure 27: School C polygon features
Table 12: School C polygon attributes

4.2.5.4 School D

Ten learners participated in the exercise in School D (indicated in Figure 28). The learners captured 22 point, 24 line, and 24 polygon features as indicated in Figure 29. The total number of features collected was 70.

Figure 28: School D layout (source: City of Ekurhuleni 2018 imagery)
The point features that were captured included a cell phone tower, a dust bin, a toilet, taps, water tank, trees, a description board, stairs, an office, a container, and a zozo (a shack) as indicated in Figure 30 and Table 13. Table 13 further indicates that some features were captured with incomplete attributes.
Table 13: School D point attributes

Line features

Figure 31 and Table 14 indicate the line features that were captured, including lines, a water passage, a waterway, streams, and a corridor wall. The assembly was also captured as a line feature instead of a polygon. Table 14 further indicates a feature that was captured with incomplete attributes.

Figure 31: School D line features
Table 14: School D line attributes

<table>
<thead>
<tr>
<th>Polyline</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>Trees</td>
<td>group of trees</td>
</tr>
<tr>
<td>112</td>
<td>Classrooms</td>
<td>group of classrooms</td>
</tr>
<tr>
<td>113</td>
<td>Library</td>
<td>group of books</td>
</tr>
<tr>
<td>114</td>
<td>Rusted tanks</td>
<td>group of rusted tanks</td>
</tr>
<tr>
<td>115</td>
<td>Container</td>
<td>group of containers</td>
</tr>
<tr>
<td>116</td>
<td>Water reserve</td>
<td>group of water reserve</td>
</tr>
</tbody>
</table>

Polygon features

The polygon features collected (as indicated in Figure 32 and Table 15) included shacks, a mobile class, trees, classrooms, the library, rusted tanks, a container, and a water reserve. Table 15 further indicates features that were captured with incomplete attributes.

Figure 32: School D polygon features
4.2.5.5 School E

In School E (indicated in Figure 33), 12 learners participated in the study. They captured 34 point, 22 line, and 24 polygon features as indicated in Figure 34. The total number of features collected was 80.

Figure 33: School E layout (source: City of Ekurhuleni 2018 imagery)
Point features

Figures 35 and Table 16 indicate the features that were captured by the participants, which included trees, a light, a flag holder, a rod, a road, a tap, a drain, the car park, a water hose, and a dump bin (usually called a rubbish bin).
Table 16: School E point attributes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterways</td>
<td>Back to school</td>
</tr>
<tr>
<td>Pavement</td>
<td>Classroom</td>
</tr>
<tr>
<td>Teachers' parking lot</td>
<td>Office</td>
</tr>
<tr>
<td>Fence</td>
<td>Toilet block</td>
</tr>
<tr>
<td>Roads</td>
<td>Amazenke wemvula</td>
</tr>
<tr>
<td>Assembly</td>
<td>Shelter that learners walk under</td>
</tr>
</tbody>
</table>

Figure 36: School E line features
Table 17: School E line attributes

Polygon features

The polygon features that were captured included blocks of classrooms, toilets, zozos, a class container, a house, a chips container, a garage and a parking lot (as indicated in Figure 37 and Table 18). An Apollo light was also captured as a polygon, which is not the norm as lights are usually captured as points.

Figure 37: School E polygon features
4.3 Part 2: Questionnaire Analysis

Before data analysis, the researcher has to check the measurement level of the data that has been collected. The data can be categorised into variables, which are divided into categorical and numerical data classes. It is important to code every response including non-responses using a code sheet. The non-responses can be regarded as “Skip” responses (Fouché and Bartley, 2012). In this study, the non-responses were not left blank but they were categorised as “Skip” responses.

Microsoft™ Excel was used to analyse the quantitative data. The spreadsheet data was analysed and interpreted using univariate analysis, which is the simplest form of data analysis that analyses one variable at a time mainly with a view of describing that variable in a frequency distribution format (Fouché and Bartley, 2012).

4.3.1 Gender of participants

The researcher requested the teachers to select the participants in the study. It was therefore important for the respondents to indicate their gender when completing the questionnaire for the researcher to assess the gender balance of the participants.

Figure 38: Gender of the participants
Figure 38 indicates that 48 (59%) of the respondents were female and 34 (41%) male.

4.3.2 Access to a computer at school

The participants were asked if they have access to a computer at school. Figure 39 indicates that 57 (70%) of the participants have access to computers at school while 25 (30%) do not have access to computers in their schools. Kingston et al. (2012) defined mobile technology as portable (handheld) computers, usually with GPS capability (e.g. PDAs and smartphones). This question was important because of the *portable handheld computer* component in the definition of mobile GIS. This is also the reason why Innes and Van Der Willigen (2008) assumed in their study that access to computers would influence the participants’ ability to perform well on a computer-assisted learning program.

![Access to a computer](image)

*Figure 39: Access to a computer*

4.3.3 Familiarity with GIS

The participants had to indicate if they were familiar with GIS. Figure 40 indicates that 65 (79%) participants had a GIS lesson in the previous grade (grade 10). Sixteen (20%) is learning GIS for the first time in grade 11 and only one (1%) is not doing GIS in this grade. The study was conducted based on the premise that the learners were introduced to GIS in the previous grade. It had to be confirmed whether all participants did take GIS in the previous grade, which would confirm their knowledge of GIS concepts used in the exercise.
4.3.4 Mapwork in the classroom

The participants were asked if they do mapwork in the classroom, and all 82 (100%) agreed that they do mapwork in the classroom. There is a relationship between mapwork and fieldwork, which is highlighted by the Department of Basic Education (2011) in terms of locating the exact position, relative position, and distance. The study conducted by Britz and Webb (2016) also suggested that mapwork is familiar to the learners. It becomes a foundation in introducing GIS theory and practice, which is unfamiliar to the learners.

4.3.5 Mapwork frequency

The participants were then asked how often they do mapwork in the classroom. Figure 41 indicates that 60 (73%) of the respondents do mapwork once a term, 15 (18%) once a week, five (6%) once a month, one (1%) once a year, and another, one (1%) once a year.

Figure 40: Familiarity with GIS

Figure 41: Mapwork in the classroom
4.3.6 Previous experience with any mobile device in fieldwork

The participants were asked if they used any mobile devices such as smartphones, tablets, and GPS devices outside the classroom in fieldwork.

![Previous experience with any mobile device in fieldwork](image)

Figure 42: Previous experience with any mobile device in fieldwork

The Department of Basic Education (2011) prescribes that learners are supposed to collect and record data through fieldwork using a variety of techniques. Fieldwork plays an essential role in GIS education because it teaches students how to collect raw data by themselves, which provides an opportunity to teach geospatial skills and technological theories (Armstrong and Bennett, 2005).

Figure 42 indicates that 39 (48%) participants have used a mobile device in fieldwork before, while 38 (46%) have never used a mobile device in fieldwork, four (4%) did not have any experience of fieldwork, and one (1%) did not respond to the question.

4.3.7 Mobile GIS relevance to learners

The participants were asked if they thought that mobile GIS is relevant to them as learners. Figure 43 indicates that 72 (88%) participants agreed that mobile GIS is relevant to them as learners, seven (9%) were not sure, two (2%) felt that it is not relevant, while one (1%) did not respond to the question.
4.3.8 Problems experienced with mobile GIS

The participants were asked to indicate the problems they experienced when they used mobile GIS. Table 19 indicates that 31 (38%) participants experienced no problems when they used mobile GIS. Twenty (24%) were able to capture geographic features but not their attributes. Eleven (13%) experienced signal loss, nine (11%) indicated that the screen was too small, one (1%) indicated that the keyboard was not user-friendly, one (1%) indicated signal loss and that the map was too small, one (1%) indicated that the screen was too small, the map was too small and also that they were able to capture geographic features but not their attributes. The other one learner (1%) indicated that it was their first time doing it with a phone.

The challenges cited by the participants could be associated with issues relating to the design of the devices (such as screen size and resolution, keyboard/keypad, memory, and optional additional memory) and also that the GPS in a smartphone for location awareness would not work and might even give seriously erroneous results where the signal of three or more satellites is not available (Li and Brimicombe, 2013). Kingston et al. (2012) observed that during their study some students complained about the PDAs being a little awkward to use during the mobile technology exercise due to their small screens, fonts, and buttons.

Table 19: Problems experienced with mobile GIS

<table>
<thead>
<tr>
<th>Q8 – What problems did you experience when you were using mobile GIS</th>
<th>No. of participants</th>
<th>% of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map too small, signal loss.</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>
Q8 – What problems did you experience when you were using mobile GIS

<table>
<thead>
<tr>
<th>Problem</th>
<th>No. of participants</th>
<th>% of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen too small, map too small, I was able to capture geographic features but not their attributes.</td>
<td></td>
<td>1%</td>
</tr>
<tr>
<td>Keyboard not user-friendly.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Other: It was my first time doing it with a phone but it was fine honestly.</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Map too small.</td>
<td>7</td>
<td>9%</td>
</tr>
<tr>
<td>Screen too small.</td>
<td>9</td>
<td>11%</td>
</tr>
<tr>
<td>Signal loss.</td>
<td>11</td>
<td>13%</td>
</tr>
<tr>
<td>I was able to capture geographic features but not their attributes.</td>
<td>20</td>
<td>24%</td>
</tr>
<tr>
<td>None.</td>
<td>31</td>
<td>38%</td>
</tr>
</tbody>
</table>

4.3.9 Application of classroom knowledge to mobile GIS exercise

The participants were asked if they were able to apply GIS/geography/mapwork classroom knowledge when they were doing the mobile GIS exercise.

Figure 44 indicates that 78 (95%) of the participants were able to apply classroom knowledge to the mobile GIS exercise. Three (4%) participants did not answer the question while one (1%) indicated they were unable to apply knowledge obtained in the classroom to this exercise. This confirms the findings of the study conducted by Peacock et al. (2018) that exposing students to fieldwork assists them in applying theory to practice.

![Application of classroom knowledge to mobile GIS exercise](image)

*Figure 44: Application of classroom knowledge to mobile GIS exercise*
4.3.10 Time taken to complete the exercise

The participants were asked how long it took them to finish the mobile GIS exercise. Figure 45 indicates that 24 (29%) of the participants completed the exercise in less than 30 minutes. Twenty-one (26%) completed it in less than 40 minutes, 16 (20%) in less than 20 minutes, 13 (16%) in more than 40 minutes, six (7%) less than 15 minutes, and two (2%) did not respond to the question.

![Figure 45: Time taken to complete the exercise](image)

4.3.11 Attitude towards mobile GIS

The participants were asked if they enjoyed using mobile GIS. Figure 46 displays that 78 (95%) of the participants enjoyed using mobile GIS, three (4%) did not enjoy using mobile GIS while one (1%) did not respond to the question. In their study, Ida and Yuda (2012) also found that students’ satisfaction with the classes in fieldwork was mostly high and the students pointed out that a great deal of time can be saved by using cellular phone GIS.

![Figure 46: Attitude towards mobile GIS](image)
4.3.12 Mobile GIS exercises to assist in learning more about GIS

The participants were asked if they thought mobile GIS exercises can help them learn more about GIS. All 82 (100%) respondents agreed that mobile GIS exercises can help them learn more about GIS. This is in line with the findings of Chuang (2015) in which all the students held the view that fieldwork could improve their understanding of GIS learning.

4.3.13 Mobile GIS exercises in a geography lesson

The participants were asked if they would prefer to do more mobile GIS exercises in a geography lesson.

Eighty (98%) of the respondents would prefer to do more mobile GIS exercises in geography lessons while two (2%) would prefer not to do them as indicated in Figure 47. Chuang (2015) found in his study that over 90% of the students were inclined to take more fieldwork exercises in their GIS classes. Neumann and Kutis (2006) in their mobile GIS in geologic mapping study also found that most students expressed interest in doing more field exercises to get more practice.

![Pie chart showing 98% Yes, 2% No](image)

*Figure 47: Mobile GIS exercises in a geography lesson*

4.3.14 Proposed frequency of mobile GIS exercises

The participants who indicated that they would like to do more mobile GIS exercises during a geography lesson were asked how often they would like to do these lessons. Figure 48 indicates that 41 (50%) of the participants would like to do mobile GIS exercises once a week, 26 (32%) would like to do them every day, 12 (15%) once a month, while one (1%) once a term, one (1%) once a year, and one (1%) did not respond to the question.
4.3.15 Any other comments regarding mobile GIS

The participants were asked if they had any other comments regarding mobile GIS. Fourteen (16%) of the participants had no comments to this question, three (4%) did not respond to this question, three (4%) responded that the geographical features are elaborated more clearly and easily understood, one (1%) responded that it challenged them while they were using it. Below are the other individual responses from the participants:

- “I like GIS the most, so I would like to do it often.”
- “Yes, GIS made us realize that we have point, line, polygon feature inside our schoolyard.”
- “Yes, mobile GIS really helped me to understand more about point, line and polygon features.”
- “I think GIS should be more implemented to school learners and people out there to help them gain knowledge and info about today’s systems that make life easier.”
- “I think GIS mobile should be used at schools in order to capture information and there will be no need for a textbook when doing GIS.”
- “Yes, it was nice using it and I at least have experience in mobile GIS and I never thought of it.”
- “It’s a great experience and its good for learning new things.”
- “It is very interesting and easy to do.”
- “Mobile GIS is easy to use and understandable.”
- “Yes, mobile GIS should be introduced at high school year at which GIS theory is introduced.”
- “It is practical, so it is easy to understand GIS better than theory.”
- “Yes, I had a great day using GIS mobile and I enjoyed it.”
“Using mobile GIS makes learning much easier and I will remember whatever I did because it is practical.”

“It's interesting and it should be used in schools.”

“I wish that it would be introduced in more schools.”

“I loved it a lot.”

“Yes, I am very happy because now I know how to use mobile GIS but it became difficult when capturing the polygon features because of the slopes, so the polygon became different.”

“It can be a little confusing due to the different types of slopes found on the school field but it is indeed a great practical to do and it is enjoyable.”

“I think mobile GIS is a great way for learners to have better understanding and you get to see it being done in real life.”

“It is the best it makes everything to be easier to understand when it comes to GIS.”

“Yes, using GIS physical helped me to realize the importance of it.”

“It is more useful in helping us understand more about GIS.”

“What a great system to use. Easy small and very fast to use. A great pleasure to use it indeed.”

“Mobile GIS increases our knowledge of data collection.”

“My comment is that the mobile GIS is great, especially using it to capture data.”

“It's fun and easy to handle device, to be honest it would be awesome to use when travelling long distances therefore you'd know how to find your way back by just looking at the points you've used. Can I have mine?”

“It was enjoyable and now I am more sophisticated with mobile GIS as it was my first time using it.”

“I am very happy because I have learnt a little more about mobile GIS.”

“Yes, maybe we will have to try using GIS mobile because it won't be difficult to use them.”

“I think using a mobile GIS is a simple way of marking features that are located in our school or anywhere in the area.”

“Mobile GIS should be provided to learners at schools as it is easier to use it than reading it in class.”

“I enjoyed the GIS exercise.”

“Yes, GIS help us to know an information about a location.”

“Yes, GIS helps us to know more about finding a location.”

“GIS practice is a very warming practical that brings about more understanding in mind, that it is real thing captured by people and anyone can take part in it, only if they are willing to give themselves a chance.”

“Yes, maybe we will have to try using GIS mobile because it won’t be difficult to use them.”

“I think using a mobile GIS is a simple way of marking features that are located in our school or anywhere in the area.”
• “Yes, if we do practicals of GIS we won’t be able to fail the topic because it will be easy for us to remember.”
• “It is quite interesting I would like to use it more often.”
• “The device is easier to use and can help learn more about GIS in class.”
• “Besides that the experience was a pleasant one. I don’t have any comment.”
• “Mobile GIS is really good because it helps a lot, we may use it instead of hardcopy.”
• “Yes, I think schools should use mobile GIS more coz it helps in remembering and answering exam questions.”
• “Yes, learners in schools should be encouraged to do more practical lessons and schools should also support it.”
• “It helps you locate and see; also know more about geographical features that we do not take note of on a daily basis.”
• “Mobile GIS is fun and interesting.”
• “Mobile GIS is better than theoretical GIS.”
• “Mobile GIS can locate your current location and accumulate or store data precisely across the current location. Results will be accurate.”
• “Yes, reason being that it is very interesting and a good way to learn about features.”
• “Yes because using mobile GIS it makes you to be lucid when you think in order to collect information using lines etc.”
• “Yes, because mobile GIS makes life easier since ever you can collect information in less than 20 min.”
• “Yes, I will like to use mobile GIS more often as that will help me understand the topic of GIS lotter [better].”
• “The information I learnt about GIS made me to consider GIS as a career.”
• “I have learnt a lot about GIS and I had fun doing the mobile GIS exercise.”
• “After using GIS mobile I have learnt a lot and gained knowledge about it.”
• “Mobile GIS can make things easier for geographically topics in classrooms.”
• “Using mobile GIS is great and much easier and also interesting.”
• “GIS is a great device that helped me understand more about the chapter, I would really love to use it again.”
• “Yes, the experience was amazing because I got a chance to learn and understand more about GIS. Let’s do this again please.”
• “Wish we could have mobile GIS in our school because they are very easy to use.”
• “It was fun to use and also putting more experience to myself regarding to GIS courses.”
• “Mobile GIS is more effective and helps us to understand more about GIS.”
• “Yes, it was very interesting and I have learnt a lot about GIS.”
4.4 Summary

This chapter presented and discussed the findings obtained from the mobile GIS exercise and questionnaires. The first section of the chapter presented results gathered from the mobile GIS exercise. The second part presented the questionnaire results. The findings of the study addressed all objectives and questions of the study. The findings confirmed that mobile GIS can be used in schools. The learners were able to capture geographic features within their school premises. All learners agreed that mobile GIS exercises can help them learn more about GIS. Most learners enjoyed using this tool as indicated in Figure 46. They would also like to do more GIS exercises as indicated in Figure 47.
CHAPTER 5: SUMMARY OF THE MAJOR FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In the previous chapter, the data collected was presented, analysed and interpreted. This chapter provides a summary of the findings, presents the conclusion, and makes recommendations as well as suggestions for further studies. This study was conducted with the purpose of investigating the application of mobile GIS in grade 11 Tembisa secondary schools. The objective of the study was to find answers to the following questions:

1. Can learners use mobile GIS?
2. Can the learners identify geographic features within their school premises and capture them in a spatial data format using mobile GIS?
3. Is mobile GIS relevant to geography learners?
4. Can mobile GIS assist learners in enhancing their GIS knowledge?
5. What are the major challenges and opportunities associated with using mobile GIS in secondary school education?

5.2 Summary of the Findings

From the results gathered in Chapter 4, this chapter summarises the findings based on the research questions.

The mobile GIS data collection exercise was completed within 60 minutes, which is equal to two teaching periods. As Li (2007) advocated, the mobile GIS user interface must be user-friendly. In this study, learners found mobile GIS practical, easy to use, and understandable. Mobile GIS exposed the learners to new technology. They found the mobile GIS device is easy to use, and it can help them learn more about GIS in the classroom.

Learners collected 142 points, 112 lines, 110 polygons, and 182 attachments (pictures). Through this exercise, they were able to recognise existing point, line, and polygon features inside their school premises that they were not aware of prior to the exercise. However, when the data was examined, it was noted that several polygons had errors in terms of shape. Some learners expressed in the questionnaire that they found it difficult to capture polygons. In their study, Pánek and Glass (2018) also noted that students found it easy to collect point data with Collector for ArcGIS; however, the application interface was highly criticised for collecting polygons. It was also noticed that features such as trees, a person, a bin, a car, a transformer, an electric box, and living birds were captured as polygons, which is not the norm.

Various learners captured features such as a netball court, grass field, assembly and parking lot as line features, which was also unexpected. The learners were expected
to capture features in the appropriate formats. Breetzke et al. (2011) indicated in their study that learners were asked to identify points, lines, and polygon features on the 1:50 000 topographic maps. Later on, they drew maps of where they live using points, lines, and polygons to represent the real world as a model. Moreover, the topic of different types of data (line, point, area, and attribute) is covered in grade 11 (Department of Basic Education, 2011).

The study revealed that even though learners could capture features, some of the features’ attributes were not populated. The questionnaire confirmed that 24% of the learners were able to capture geographic features, but not their attributes. According to Maguire (1991), the geographical location is deemed more important than its attributes. However, in this study, it was important for learners to capture the spatial location of a feature and then to provide its description. Even though the learners were requested to spread out and not capture features that had already been captured by other learners, in some instances it was noticed that different devices/learners captured specific features more than once.

Most learners agreed that mobile GIS is relevant to them as learners and that it can help them learn more about GIS. They felt that mobile GIS should be introduced in the same high school year as GIS theory. Furthermore, the learners found mobile GIS practical, easy to understand, and better than theory; therefore, mobile GIS would assist them in passing the GIS exam paper. This finding was confirmed in Position IT (October 2015) when the Northern Cape Department of Education discovered that grade 12 learners were not answering exam questions relating to GIS in the Geography Paper 2 because of their lack of exposure to the practical side of GIS. It was further confirmed that the learners found the section challenging as it requires hands-on experience in order to be applied.

Similar to other mobile GIS case studies, challenges were also reported in this study, including learners not being able to populate the feature attributes, experiencing signal loss, and finding that the handheld device’s screen and map were too small and that the keyboard was not user-friendly. These challenges are similar to those reported by Li and Brimicombe (2013) and Kingston et al. (2012) relating to the design of the devices (such as small screen size and resolution, keyboard/keypad, small fonts, and buttons).

## 5.3 Conclusions

This study investigated the application of mobile GIS in grade 11 Tembisa secondary schools. It was organised into five chapters. Chapter 1 of this study gave the background and contextual setting of this study. Chapter 2 reviewed the literature related to the study in terms of relationships between geography, GIS, mobile GIS, and fieldwork, and how these concepts are applicable to education in secondary schools in South Africa. Chapter 3 presented the step-by-step research methodology process that was undertaken in this study. Chapter 4 described the presentation,
interpretation, and analysis of data collected in this study, which was done through a mobile GIS exercise and questionnaires. Lastly, Chapter 5 gave a summary, conclusion and recommendations, and identified areas for further research.

Mobile GIS was a practical way of introducing learners to GIS. It provided learners with a new learning resource, which enabled them to combine GIS with fieldwork. The conclusion arising from this study is that geography learners in Tembisa secondary schools can apply classroom knowledge practically and that they are ready and eager to use mobile GIS in their lessons. The learners were able to present the real-world model (their schools) in point, line and polygon features. As indicated by Houtsonen (2006), they were able to extract practical examples of locational data from their everyday surroundings using mobile GIS services. Although some learners expressed difficulties in capturing polygons and did not populate the attributes, the learners found mobile GIS is easy to use, and stated that it can help them learn more about GIS in the classroom. Mobile GIS was also seen as a tool that can assist learners in passing their GIS exam paper. In his study, Carlson (2007) also found that students respond positively to practical applications when they are applied to theory.

One limitation that should be noted is that some of the mobile GIS components were not explored in this study. The mobile GIS exercise was only based on data collection (fieldwork component) and the learners were able to collect data within the time allocated for the exercise. The data collected was synchronised in the ArcGIS Online platform. However, the learners did not get the opportunity to view and analyse the data that they had collected on the ArcGIS Online platform. As a result, they did not get the opportunity to report to their classmates on the data that they collected. This prevented them from getting feedback from their fellow classmates. By looking at the data that was collected as polygons (such as trees, a person, a bin, a car, transformer, electric box, and living birds) and data that was collected as line features (such as a netball court, grass field, assembly and parking lot), other learners would have pointed out that these features were not supposed to be captured in these formats. Since this study only focused on the data collection part, which was evident that it could be done within 60 minutes, another additional class period is necessary to view, analyse and present the data collected.

5.4 Recommendations

Based on the spatial data collected, the questionnaires, and the learners’ enthusiasm and readiness about the mobile GIS exercise, the project showed that there is no reason for mobile GIS not being introduced in grade 11 geography lessons in secondary schools.

A mobile GIS exercise (only data collection) can be completed within 60 minutes, therefore making it possible to introduce mobile GIS in schools within class periods. The Gauteng Department of Education can select a few schools where mobile GIS can be piloted. The Gauteng Department of Education can provide mobile handheld
devices that are integrated with GPS functionality with the capacity to work with offline maps; in this way, mobile GIS will be integrated easily into schools.

Li and Brimicombe (2013) mentioned GIS servers and wireless mobile telecommunication networks (connectivity) as key elements of mobile GIS. Therefore, the Gauteng Department of Education can prepare and enable a centralised ArcGIS Online environment to synchronise data captured by the learners during the mobile GIS exercise. The teachers will access the ArcGIS Online platform and present it to the learners for data viewing and analysis purposes following the method advocated by Demirci (2011) of implementing a GIS-based exercise in a classroom with only one teacher and one computer. Fleischmann and Van der Westhuizen (2017) also proposed ArcGIS Online as a teaching avenue that could be explored in the South African education context. All these technologies combined will be useful in ensuring the application of mobile GIS secondary school education.

5.5 Suggestions for Future Research

In research, any ideas a researcher has for future research can be discussed as this can provide leads for other researchers and practitioners toward areas deemed to be important after gaining experience with the current research project (Nishishiba et al., 2014). From the current study, a number of topics emerged that may require further attention in the field of mobile GIS in secondary schools not covered in this study.

The current study investigated the application of mobile GIS in grade 11 in Tembisa secondary schools. It is therefore suggested that other similar studies be conducted that include both teachers and learners. This would provide a complete outlook on how mobile GIS can be applied in secondary schools. The topics that could be considered for future research are as follows:

- Providing mobile GIS training to teachers and learners
- Identifying and developing relevant mobile GIS content for learners
- Investigating a comprehensive and cost-effective mobile GIS model for South African schools
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APPENDIX A: DATA PREPARATION FOR MOBILE GIS EXERCISE

**Mobile GIS Project: Data Preparation in ArcGIS Desktop**

Creating a geodatabase

A file geodatabase named MobileGISProject was created as indicated in Figure 49.

![Figure 49: MobileGISProject](image)

Domains as indicated in Figure 50 were created for learner and gender fields for participants to populate these fields easily and quickly when collecting data.

![Figure 50: Creating domains](image)
Creating feature classes

New feature classes were created as indicated from Figure 51 to Figure 65.

Polygon features

![Polygon feature class](image1)

**Figure 51: Polygon feature class**

![Polygon feature class coordinate system](image2)

**Figure 52: Polygon feature class coordinate system**
Figure 53: Polygon feature coordinate system XY tolerance

Figure 54: Polygon database storage configuration
Figure 55: Polygon feature class fields

Line features

Figure 56: Line feature class
Figure 57: Line feature class coordinate system

Figure 58: Line feature coordinate system XY tolerance
Figure 59: Line database storage configuration

Figure 60: Line feature class fields
Point features

Figure 61: Point feature class field

Figure 62: Point feature coordinate system
Figure 63: Line feature coordinate system XY tolerance

Figure 64: Point database storage configuration
Attachments were enabled by right clicking on each feature class.

Figure 66: Creating attachments
**Sharing the Mobile GIS Project on ArcGIS Online**

For the data created in ArcMap to be accessible to every mobile device, it had to be published to an organisational account on ArcGIS Online. Figure 67 to Figure 72 provide all the steps that were taken to publish the service.

![Publish as Service](image)

*Figure 67: Publishing the mobile GIS project*

![Select an existing connection](image)

*Figure 68: Selecting an existing ArcGIS Online connection*
Figure 69: Publishing MobileGIS with feature access capabilities

Figure 70: Enabling all operations on MobileGIS

Figure 71: Providing MobileGIS tags and description
Successfully publishing the service on ArcGIS Online

ArcGIS Online

Figure 73 and Figure 74 display the service that was successfully published on ArcGIS Online, and show that the three feature classes can be edited by the learners.
Mobile Handheld Device

Blackview BV6000 Android 7.0 smartphones were used for the study. Collector for ArcGIS was downloaded from Google Play to all ten Blackview BV6000 devices and connected to the ArcGIS Online organisational account. Thereafter, the mobile GIS exercise map was downloaded on each device for the exercise to begin as indicated in Figure 75.

Figure 74: Editable features on ArcGIS Online

Figure 75: Mobile GIS Exercise map, features to be captured and attributes
Collected data

Figure 76 displays the data collected by the learners in the ArcGIS Online environment.

Figure 76: Captured data on ArcGIS Online

Figure 77 shows how collected data was exported from ArcGIS Online to ArcMap.

Figure 77: Captured data on ArcGIS Online to be opened in ArcMap
Data on ArcMap

For data to be opened on ArcGIS Desktop, a connection first had to be established with ArcGIS Online, thereafter it was available in ArcGIS Desktop as indicated in Figure 79.

Figure 78: Establish connection with ArcGIS Online

Figure 79: Captured data opened in ArcMap
APPENDIX B: MOBILE GIS EXERCISE

In the GIS lessons in grade 10 and in this grade you have learnt that geographic features are represented in points, lines and polygons. In this exercise, you will use mobile GIS to identify all these features within your school premises, fill in their appropriate attributes, and capture their photos. After this exercise you will respond to the questionnaires relating to the exercise.
APPENDIX C: MOBILE GIS MANUAL

In this exercise, you will identify and capture point, line and polygon features within the school premises using mobile GIS.

With the map open, you are ready to capture point, line and polygon features within the school premises.

Below are the instructions of how to capture these features:

1. **Point features**

1.1 Select **Collect a New Feature**.

1.2 Select Point Features circled in red as shown in the image below.
1.3 Wait until you see the coordinates in long and lat then complete the form in the image below by populating these fields: FeatureName, Description, CapturedBy, Gender.

1.4 After populating all the fields you may also add a picture by clicking on the icon circled in red.

1.5 Then select add attachment from camera as shown in the image below.

1.6 Press to take a picture.

1.7 Select to save the picture or to delete it.
1.8 Click on the tick sign circled in red as shown in the image below to save the point feature that you have just captured.

![Image showing tick sign]

1.9 Close the captured point features in the button circled in red.

![Image showing close button]

2. **Line features**

2.1 Select **Collect a New Feature**.

2.2 Select Line Features circled in red below.

![Image showing line features option]
2.3 Complete the form by populating these fields: FeatureName, Description, CapturedBy, Gender.

2.4 Click on stream circled in red at the bottom, then click on map circled in yellow to view your current location

2.5 Start walking following the pattern of the line feature that you are capturing.

2.6 At the end of the line feature click on the tick circled in red as shown in the image below to complete capturing the feature

2.7 Close the captured line features in the button circled in red as shown in the image below
Please refer to steps 1.4 to 1.7 if you want to take a picture.

3. Polygon features

3.1 Select **Collect a New Feature**.

3.2 Select Polygon Features circled in red below.

3.3 Complete the form by populating these fields: FeatureName, Description, CapturedBy, Gender.

3.4 Click on stream circled in red in the image (next page), then click on map circled in yellow to view your current location.

3.5 Start walking following the pattern of the polygon feature that you are capturing. When capturing a polygon your end point will be where you started walking/capturing.
3.6 When you get to the end point click the tick circled in red as shown in the image below to finish capturing.

![Image of a device screen with a tick circled in red.]

3.7 Close the captured polygon features in the button circled in red as shown in the image below.

![Image of a device screen with a close button circled in red.]

Please refer to steps 1.4 to 1.7 if you want to take a picture.
APPENDIX D: QUESTIONNAIRE

QUESTIONNAIRE: AN INVESTIGATION OF THE APPLICATION OF GIS IN SECONDARY SCHOOLS: A CASE STUDY OF GRADE 11 STUDENTS IN TEMBISA, GAUTENG, SOUTH AFRICA

This questionnaire is based on the previous mobile GIS exercise where you were tasked to identify and capture geographic features in point, line and polygon features within your school premises.

Kindly answer the following questions by placing a tick in the appropriate box, where relevant specify your answer.

School name: ..................................................................................................................................................................................................................................................

1. What is your gender?
   □ Female
   □ Male

2. Do you have access to a computer at school?
   □ Yes
   □ No

3. How familiar are you with Geographic Information System (GIS)?
   □ I have never heard about GIS.
   □ I had a GIS lesson in the previous grade.
   □ I am taking my first GIS lesson in this grade.
   □ I am not doing GIS in this grade.

4. Do you do mapwork in the classroom?
   □ Yes
   □ No
5. If you answered yes in the previous question, how often?

- Everyday
- Once a week
- Once a month
- Once a term
- Once a year

6. Have you used any mobile devices (smart phone, tablet, GPS) outside the classroom (in fieldwork)?

- Yes, I have used a mobile device in fieldwork.
- No, I never use a mobile device in fieldwork.
- I do not have experience of fieldwork.

7. Do you think mobile GIS is relevant to you as a learner?

- Yes
- No
- Not sure

8. What problems did you experience when you were using mobile GIS?

- Screen too small
- Map too small
- Signal loss
- Keyboard not user-friendly
- I was able to capture geographic features but not their attributes
- I was not able to capture geographic features
- I was not able to attach the image
- None
- Other…………………………………………………………………………………………………………..
9. Were you able to apply GIS/Geography/Mapwork classroom knowledge when you were doing this exercise?
   - [ ] Yes
   - [ ] No

10. How long did you take to finish the exercise?
   - [ ] Less than 15 minutes
   - [ ] Less than 20 minutes
   - [ ] Less than 30 minutes
   - [ ] Less than 40 minutes
   - [ ] More than 40 minutes

11. Did you enjoy using mobile GIS?
   - [ ] Yes
   - [ ] No

12. Do you think mobile GIS exercises can help you learn more about GIS?
   - [ ] Yes
   - [ ] No

13. Would you prefer to do more mobile GIS exercises in your Geography lesson?
   - [ ] Yes
   - [ ] No

14. If you selected yes in the previous question, how often would you like to do mobile GIS exercises?
   - [ ] Everyday
   - [ ] Once a week
   - [ ] Once a month
   - [ ] Once a term
   - [ ] Once a year
15. Do you have any other comments regarding mobile GIS?

........................................................................................................................................
........................................................................................................................................

Thank you for your participation.
## APPENDIX E: STUDY PERMISSION

**GDE RESEARCH APPROVAL LETTER**

<table>
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<tr>
<td>Name of Researcher:</td>
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<tr>
<td>Number and type of schools:</td>
<td>Six Secondary Schools</td>
</tr>
<tr>
<td>District/a/LO</td>
<td>Ekurhuleni North</td>
</tr>
</tbody>
</table>

**Re: Approval in Respect of Request to Conduct Research**

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school's and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

![Signature]

27/08/2018

Office of the Director: Education Research and Knowledge Management

7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 305 0469
Email: Faith.Tshabula@gauteng.gov.za
Website: www.education.gpg.gov.za
1. The District/Head Office Senior Managers concerned must be presented with a copy of this letter that would indicate that the said researchers have been granted permission from the Gauteng Department of Education to conduct the research study.

2. The District/Head Office Senior Managers must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.

3. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researchers have been granted permission from the Gauteng Department of Education to conduct the research study.

4. A letter/document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head OfficeSenior Managers of the schools and district offices concerned, respectively.

5. The researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and members of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.

6. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researchers may carry out their research at the sites that they manage.

7. Research may only commence from the second week of February and must be completed before the beginning of the last quarter of the academic year. If necessary, an amended Research Approval Letter may be requested to conduct research in the following year.

8. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education. It is the researcher’s responsibility to obtain written parental consent of all learners that are expected to participate in the study.

9. The researcher is responsible for supplying and utilising his/her own research resources, such as stationary, photocopies, transport, taxis and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.

10. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.

11. On completion of the study the researchers must supply the Director, Knowledge Management & Research with one hard cover bound and an electronic copy of the research.

12. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of their research to both GDE officials and the schools concerned.

13. Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

Mr Guntani Mkaladzani
Acting CES: Education Research and Knowledge Management

DATE: 07/05/2018

Office of the Director: Education Research and Knowledge Management

7th Floor, 17 Simmons Street, Johannesburg, 2001
Tel: (011) 355 0483
Email: info.ed.research@gauteng.gov.za
Website: www.education.gpg.gov.za
CONFIRMATION

Salzburg, May 2, 2018

On behalf of UNIGIS International, we the UNIGIS office in Salzburg, Austria confirm that Sifindile Nqobile Majola is enrolled in the UNIGIS International M.Sc. programme and currently works on her M.Sc. thesis with the title "An investigation of the application of GIS in secondary schools: A case study of grade 11 students in Tembisa, Gauteng, South Africa". In the framework of this M.Sc. thesis she will conduct empirical research in schools in Tembisa.

Yours faithfully,

REGINA HATHIER-STAMPF

[Signature]

Regina Hathier-Stampf