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

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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.

(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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- All 82 geography grade 11 learners who participated in the study

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

API	Application Programming Interface
CAPS	Curriculum and Assessment Policy Statement
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
ICT	Information Communication Technology
IT	Information Technology
PC	Personal Computer
PDA	Personal Digital Assistant

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, IDRISI, 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.

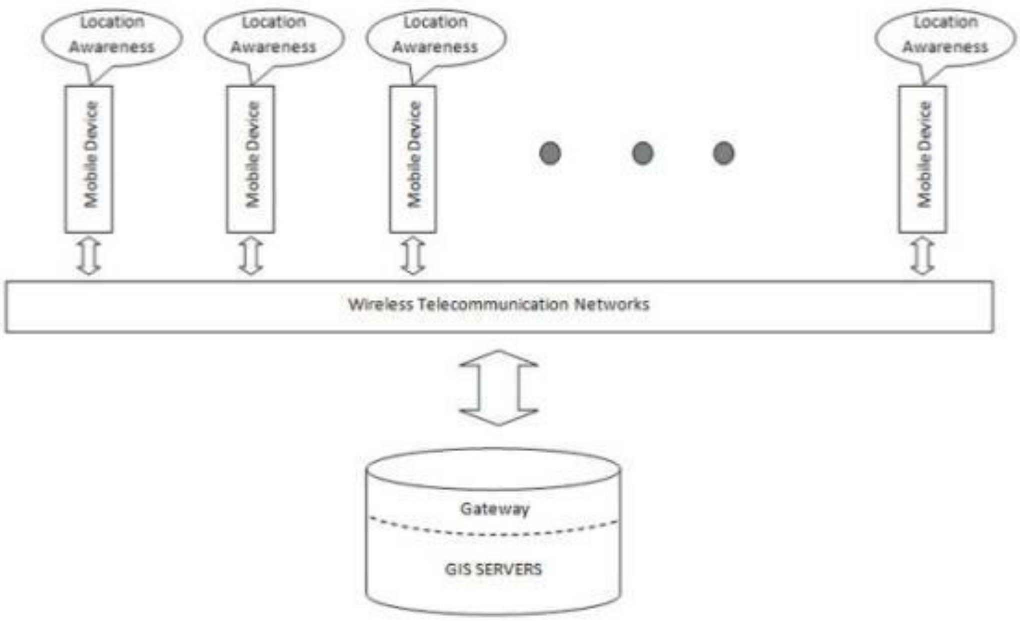


Figure 1: Key elements in mobile GIS (Li and Brimicombe, 2013)

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.

Lambrionos 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 tele-communication 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, Incekara (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 × 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.

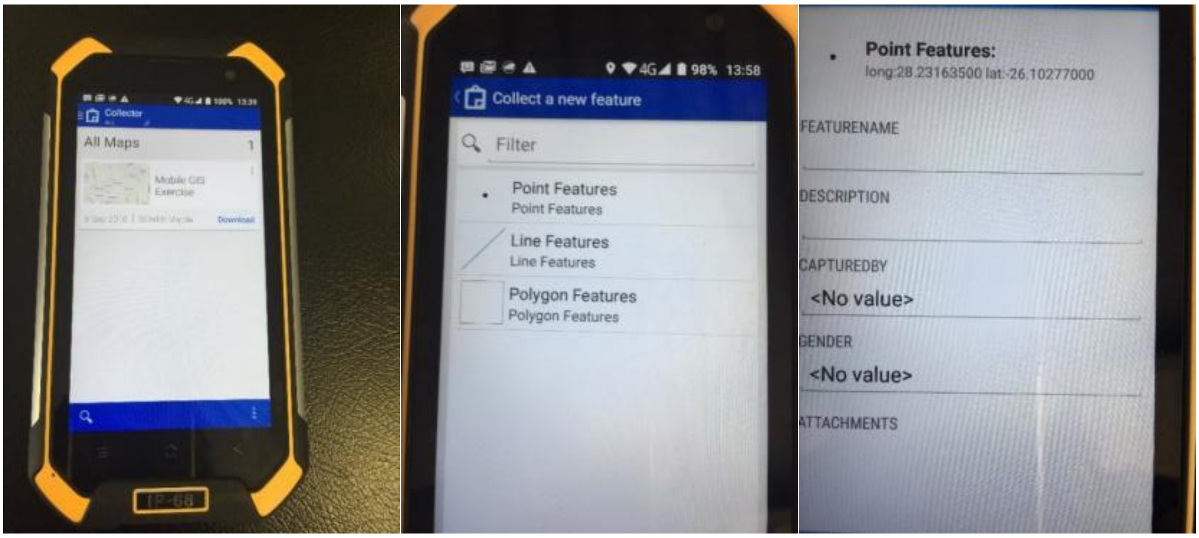


Figure 2: Blackview BV6000 mobile phone with mobile GIS exercise map, Collector for ArcGIS, features for collection

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.

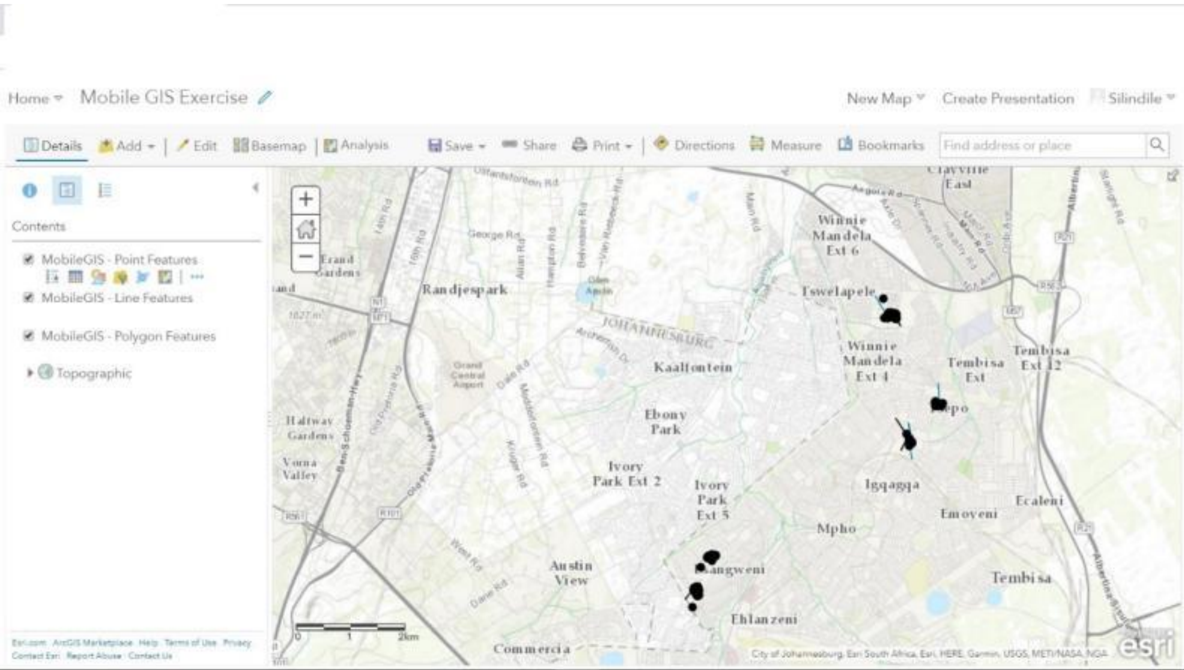


Figure 3*: Collected data displayed in the ArcGIS Online platform*

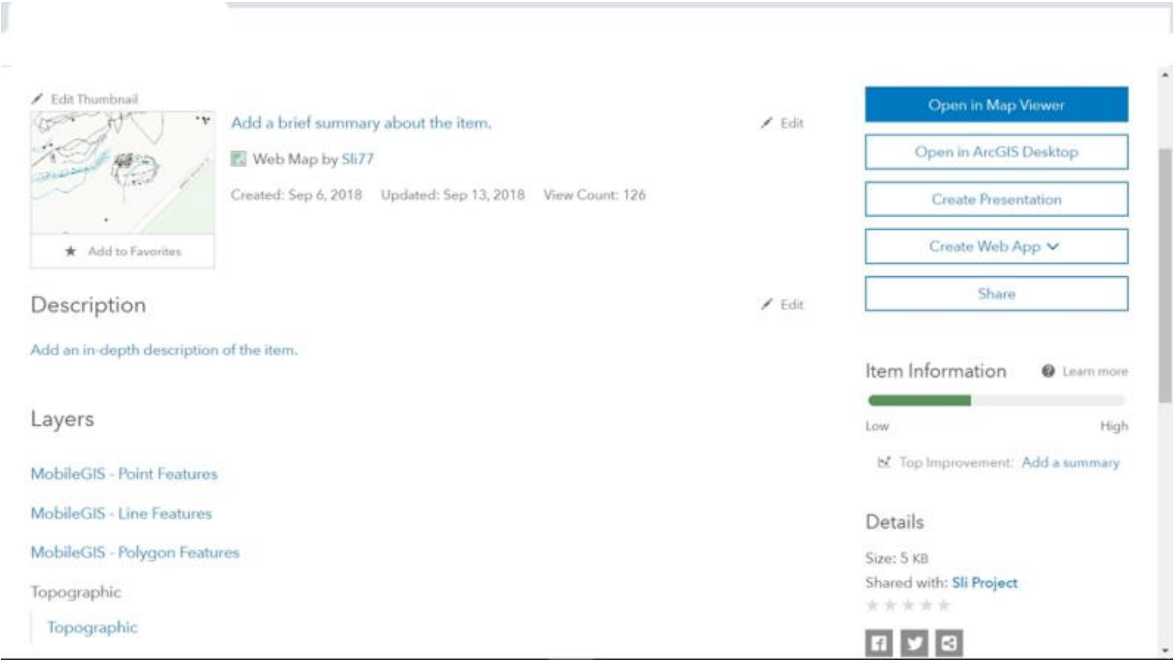


Figure 4: The ArcGIS Desktop option for viewing data

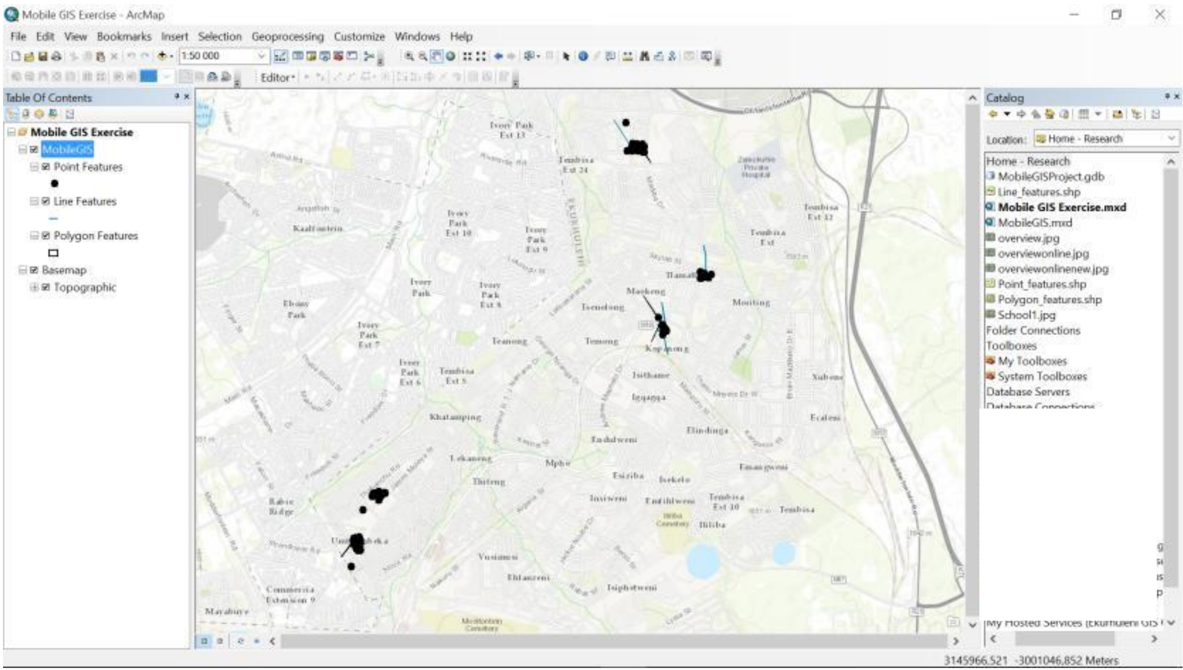


Figure 5: Presentation of data in ArcMap for further analysis

4.2.2 Data on the ArcGIS Desktop platform

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.

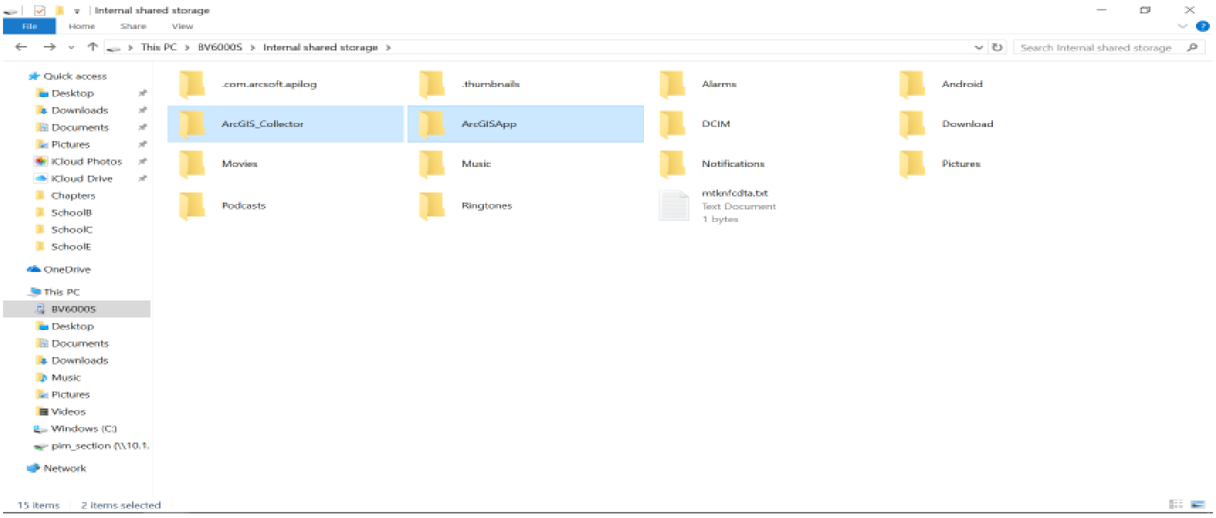


Figure 6: ArcGIS_Collector and ArcGISApp folders on the handheld device

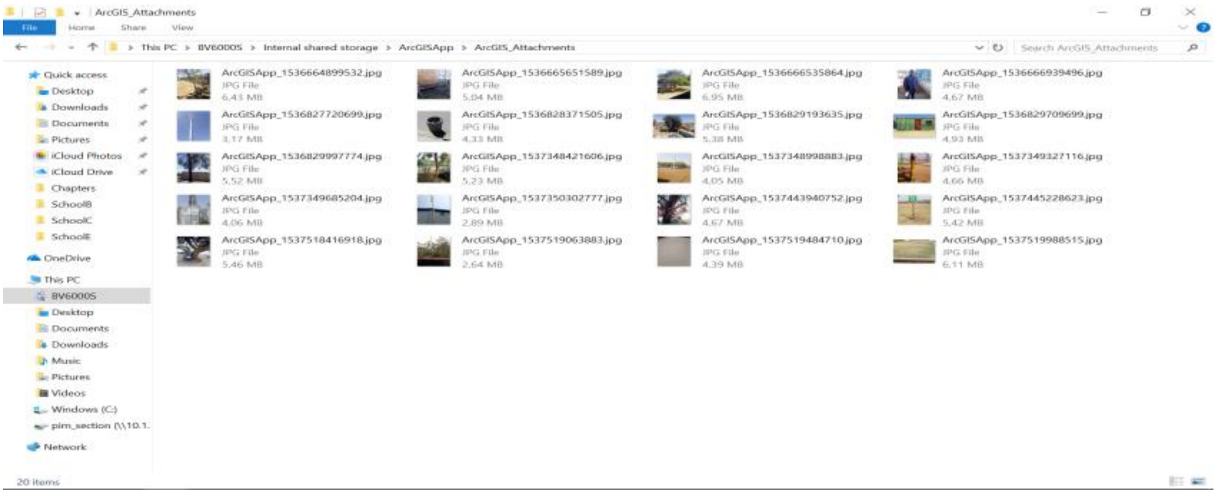


Figure 7: ArcGIS Attachments folder on the mobile GIS handheld device

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 leaners

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

Points

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	
0	Point	5	tree	green tree	Learner1	Male	{af83238
1	Point	7	tree	short one	Learner1	Male	{250a9a
2	Point	8	tree	green tree	Learner1	Male	{d2e56b
3	Point	9	Tree	green tree	Learner1	Male	{808c09
4	Point	10	our tree	green tree	Learner1	Female	{52b23c
5	Point	11	kgotsong	black tea	Learner1	Female	{72d72b
6	Point	12	Tree	Green tree	Learner1	Female	{18e450
7	Point	13	flowery tree	green leaves and pink flowers	Learner1	Female	{b978ef2
8	Point	14	Tall tree	golden green leaves	Learner 2	Female	{084e00
9	Point	15	tree	tall	Learner1	Male	{bf89e7b
10	Point	16	Toyota	blue car	Learner1	Male	{28559a
11	Point	17	flowering tree	green leaves and pink flowers	Learner1	Female	{6d8436
12	Point	18	rock	big and brown	Learner1	Female	{b3638c
13	Point	19	Pine tree	Green and short	Learner1	Male	{7f47f653
14	Point	20	tank	water tank	Learner2	Female	{ba30cf0
15	Point	21	tap	metal	Learner1	Male	{a55ab6
16	Point	22	Our garden	cultivation (spinach)	Learner1	Female	{cb9534
17	Point	23	hoga tree	short	Learner1	Female	{2e09c9
18	Point	24	tap	water resource	Learner 2	Female	{b836cd
19	Point	25	water pipe	Grey & round	Learner 2	Female	{890cf98
20	Point	26	tree	green tree	Learner1	Male	{41a3dd
21	Point	27					{c1a972
22	Point	28	grade 9 and 11 classes	double store building	Learner 2	Male	{4ce762
23	Point	29	peach plant	Green leaves with pink flowers	Learner 2	Female	{71f9a58
24	Point	30	grade 9 and grade 11 classes	double store building	Learner 2	Male	{34cb90
25	Point	31	pole	white	Learner2	Female	{26afb4e
26	Point	32	danger	still made danger	Learner 2	Female	{36cb22
27	Point	33	light pole	tall	Learner1	Male	{730578
28	Point	34	cellphone tower	tall	Learner1	Female	{45d910
29	Point	38	cellphone tower	tall	Learner1	Female	{faea755
30	Point	39	cell phone tower	tall	Learner1	Female	{b6cea4
31	Point	40	cellphone tower	it is for all networks	Learner1	Female	{5bd7de
32	Point	42	cellphone tower	long	Learner1	Male	{651b54
33	Point	43	dust bin	beautiful	Learner1	Male	{5bd574
34	Point	44	toilet	boys and girls	Learner1	Female	{99fb2d1
35	Point	45	taps	drinking water	Learner1	Male	{0c703c
36	Point	46	water tank	big and green	Learner1	Male	{e4bc21
37	Point	47	tree	weird	Learner1	Female	{e52480
38	Point	48	tree	big	Learner1	Female	{af7f2d7
39	Point	50	tree	green	Learner1	Female	{495287
40	Point	51	tree	tall and green	Learner1	Female	{cebce07
41	Point	52	description board	describes the place	Learner1	Male	{7bfc9ef
42	Point	53	tree	old	Learner1	Male	{f124431
43	Point	54	stairs	very long	Learner1	Female	{51e4ff0
44	Point	55	stairs	40	Learner1	Female	{f0c404e
45	Point	56	office				{ed56fc6

22 (0 out of 142 Selected)

Points

Table 2: Attributes of line features

Table

Lines

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	Global
0	Polyline	6	line	long	Learner1	Male	{67d1cc4c-0583-4542-9063-
1	Polyline	8	my line	side walk	Learner 2	Female	{aeaafcce-d777-4043-b3a1-
2	Polyline	9	Our line	long and wide	Learner1	Female	{d232eb7e-0fd6-45e2-9e18-
3	Polyline	10	passage	paving	Learner1	Female	{dfc89780-f643-4cd5-9a67-5
4	Polyline	11	my line	karmak	Learner 2	Female	{a6bc0a17-01d2-4d11-bae2-
5	Polyline	13	Row	water row	Learner1	Male	{4e134399-d6cb-4d84-b046-
6	Polyline	14	line	long entrance	Learner 2	Female	{30929c93-45d4-4e2a-8fdd-
7	Polyline	15	passage	long	Learner1	Male	{36100dca-999a-468f-b100-
8	Polyline	16	office passage	pavement	Learner1	Male	{1dcf37e3-e38f-4ae3-8e56-1
9	Polyline	17	passage	it is thin and it is between two staff rooms	Learner 2	Female	{2318ecb1-b6f3-4036-b72c-
10	Polyline	18	pavement	brick layered	Learner1	Male	{6bf72ded-4a2a-41b3-a9eb-
11	Polyline	19	walking stairs	brownish tiles	Learner1	Female	{c96a2f58-a743-4ff7-ab91-ff
12	Polyline	20	passage	long line	Learner2	Female	{6e543245-9c23-479a-887a-
13	Polyline	21	line	long way	Learner1	Female	{a428ba5c-db4b-43de-861d-
14	Polyline	22	passage	long and wide	Learner1	Female	{015d027c-45f4-4bfa-aa45-e
15	Polyline	23	passage	long line	Learner 2	Female	{c921a5e3-514f-4772-aa1e-
16	Polyline	24	passage	short & narrow	Learner 2	Female	{c63c12b2-5533-4499-b463-
17	Polyline	25	passage	long line	Learner1	Male	{4cd59231-493d-4536-a206-
18	Polyline	26	way	from the classes to the gate	Learner1	Male	{8e9b968f-4956-45a8-b97d-
19	Polyline	27	line to sports ground	Pavement	Learner 2	Female	{a423a1bd-0641-47fc-99eb-
20	Polyline	28	dusty road	dry grassy like walking path	Learner 2	Male	{391f1295-a434-4eae-ae88-
21	Polyline	30	line	long	Learner1	Female	{e2a60027-7c3c-4882-af38-
22	Polyline	31	line	long	Learner1	Female	{cb89fbd9-6a23-4fd8-9ed3-2
23	Polyline	32	water passage	water to pass	Learner1	Male	{1c1fa73b-c09a-4e72-9ed7-
24	Polyline	33	stream	long			{0b025b5d-1726-4639-b7aa-
25	Polyline	34	waterline	Long	Learner1	Female	{b5af42bf-3ea7-4289-85f5-d
26	Polyline	35	water passage	long	Learner1	Male	{5b2fe3c4-bc1a-4a55-8ce6-1
27	Polyline	36	passage	long	Learner1	Female	{4784ef70-418e-4571-ad2d-
28	Polyline	37	water passage	long	Learner2	Male	{009ba8b2-724b-42a8-a47c-
29	Polyline	38	water passage	water passes	Learner1	Male	{92dfa27c-b927-497b-aa61-
30	Polyline	39	water passage	long	Learner1	Female	{e037eab9-3b8d-41d2-adf2-
31	Polyline	40	waterline	long	Learner1	Female	{60fe2d55-c00d-42ad-8f7a-3
32	Polyline	41	line2	long	Learner1	Female	{63cbd3d1-498f-4069-8d11-
33	Polyline	42	line	long	Learner1	Female	{f0aea815-1b79-40cd-b807-
34	Polyline	43	line	long	Learner1	Female	{963b3dcf-9ea8-4bc9-9458-
35	Polyline	44	corridor	long	Learner 2	Female	{90143cb7-ff40-431e-a731-8
36	Polyline	46	passage way	long	Learner1	Male	{09fdf34e-9e8c-4a1b-9cc1-1
37	Polyline	47	passage	long	Learner1	Female	{a59593b2-aa18-41fe-90b0-
38	Polyline	48	passage l	long	Learner1	Female	{5f845642-17d9-46a3-857b-
39	Polyline	49	corridor	passage	Learner1	Male	{83b94810-d541-450c-881a-
40	Polyline	50	wall	grey	Learner1	Female	{70a90614-1974-4e98-9ac6-
41	Polyline	51	assembly	bricked	Learner1	Female	{e37a5a85-2815-49b9-bab0-
42	Polyline	52	water way	watery	Learner1	Male	{5fbe8c89-dcca-4ae7-a12b-c
43	Polyline	53	water passage	water passes	Learner1	Male	{f25e63c7-db3c-4c0a-a6ec-5
44	Polyline	54	stream		Learner1	Male	{10894315-251c-49e6-a4a3-
45	Polyline	55	matric pave	ling	Learner2	Female	{272cfb03-86f5-441c-a96f-76

1 (0 out of 112 Selected)

Lines

Table 3: Attributes of polygon features

Table

Polygons

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID	Shape__Are	Shape__Le
0	Polygon	7	audi s3	orange	Learner1	Male	{a4688966-fced-4b00-976e-e833d76a57d6}	80,144531	92,8219
1	Polygon	8	car	white Chevrolet	Learner1	Male	{622492ae-a7b1-41b5-b9d8-0dad342d88bf}	8,074219	21,559
2	Polygon	9	school zozo	big	Learner1	Male	{471a40c8-f854-47e3-8819-14916224b701}	92,544922	36,8904
3	Polygon	10	library	white container	Learner2	Female	{69969834-5b0f-41ec-a9f9-8e72a61dee59}	46,396484	33,2639
4	Polygon	11	house	brown	Learner 2	Female	{22abc121-0511-4d77-a3c1-dd2a36668380}	38,296875	33,1731
5	Polygon	12	school field	netball court	Learner1	Male	{5901d384-f979-4282-a710-eac1ca669746}	947,618164	117,2607
6	Polygon	13	luxury cars	blue isuzu	Learner1	Female	{6c2d8faa-885d-4d9e-8eb1-01e94ddedf69}	16,911133	25,2007
7	Polygon	14	library	white container	Learner1	Male	{525c9ae0-b3b8-403c-a316-76b0a021de66}	88,858398	53,9094
8	Polygon	15	bin	big,yellow and dirty	Learner1	Female	{964bdf9d-0a69-47e5-8069-018d964d9f74}	62,578125	32,7294
9	Polygon	16	class	short	Learner1	Female	{9c0ba478-897d-4af4-b49f-cc0dc3d69afd}	6,586914	18,3261
10	Polygon	17	ever green	container	Learner1	Male	{dadaaab3-0a40-465f-a7d9-0a80f867dbe6}	24,59082	28,9378
11	Polygon	18	bin	big,yellow and dirty	Learner1	Female	{112ae2bc-e2ed-4482-ada5-90bccab29d34}	77,665039	33,2308
12	Polygon	19	house	brown	Learner2	Female	{09fc60f6-cab4-4ab7-b59c-e39e68c6c8fe}	61,503906	38,6894
13	Polygon	20	House	security house	Learner 2	Female	{278646ef-30d6-4a19-9b9a-8bf8c112ff87}	12,657227	15,5123
14	Polygon	21	parking lot	long	Learner 2	Female	{3d85530f-cc11-4669-b4f3-3ed53b7753a6}	153,494141	54,3386
15	Polygon	22	main office	building	Learner1	Female	{2d41bcdb-276a-45e6-b2c7-df4ef6a22a42}	1515,936523	217,1335
16	Polygon	23	small house	near the gate	Learner1	Male	{26294b3d-bba9-418d-842c-09747bb59feb}	23,515625	20,3863
17	Polygon	24	person	tall and dark	Learner 2	Female	{da00b54c-820c-4487-83f3-b9348ec611bc}	2,642578	12,1990
18	Polygon	25	teacher's office	container	Learner 2	Male	{0ce2acb6-1661-4f11-aff6-9633479a1ab6}	267,445313	62,8914
19	Polygon	26	living birds	brown and black birds	Learner 2	Male	{10127c5d-8a1d-44ee-a185-13d99068e9c8}	9,725586	42,3254
20	Polygon	28	mkhokho	made of metal and cubic			{b0b6514c-f65a-46ed-a009-5e77f2dc9206}	47,25	33,4143
21	Polygon	29	zozo	short	Learner1	Female	{e9f1e4b5-bada-4609-a4bb-e1070bfa22c0}	50,026367	29,9226
22	Polygon	30	zozo	3d	Learner1	Male	{1edfce35-0dda-4650-9e13-e5e6dac72290}	41,444336	27,0558
23	Polygon	31	zozo	cubic	Learner1	Female	{61dc70cf-ae7a-44e2-8c28-2c6c8e30577e}	59,257813	30,7008
24	Polygon	32	zozo	iron	Learner1	Female	{eab76a4e-a8b8-4bf8-bde4-8ff318bfcd07}	102,255859	41,9041
25	Polygon	33	shack	store room	Learner 2	Male	{b2866314-400d-47f0-a0bd-b574fe963a61}	13,063477	19,3278
26	Polygon	34	shack	stores furniture	Learner1	Male	{e6aa1311-c104-4778-b906-f3b6a409e845}	52	29,995
27	Polygon	35	mobile class	learning room	Learner1	Male	{a59d5a53-4ca5-469e-ae5a-0ee5abb6a8a4}	248,775391	72,314
28	Polygon	36	tree	big	Learner1	Female	{c539194d-33b7-4281-b819-ba4a385b8865}	14,899414	17,0585
29	Polygon	37	tree	weird	Learner1	Female	{0772de57-4355-403e-ae42-470139ddb6d4}	1,974609	13,6553
30	Polygon	38	classroom	wider in size	Learner1	Female	{4451cc54-2b5c-4c67-8f0f-f18b41568a85}	268,326172	109,2109
31	Polygon	39	class	learning	Learner1	Female	{74b61ce3-be5c-4106-b314-3e0983518de6}	502,675781	158,594
32	Polygon	40		long and tall	Learner1	Male	{3cc82706-357f-4401-8f1d-1abf9db990d9}	8,886719	89,8453
33	Polygon	41	library	bricks	Learner1	Female	{fb1dfa4f-d476-4b59-8d1d-e36a3fac7b43}	578,118164	90,471
34	Polygon	42	water reserve	longish	Learner1	Female	{511d1364-14b6-4121-93e4-a3d62032dc4e}	2,873047	8,3210
35	Polygon	43	classes	tall	Learner1	Male	{bc15d14f-6ada-4e3b-9a20-a4ebc55c6b3c}	357,753906	162,6072
36	Polygon	44	water reserve	red	Learner1	Female	{39a154fa-05c5-4015-bf90-45385ec697b7}	3,441406	16,8649
37	Polygon	45	classroom	3d	Learner1	Male	{8fa08a39-2004-4b60-8250-87cbf286631b}	767,21875	209,0783
38	Polygon	46	classes	big	Learner1	Female	{3484d790-9c9a-45ad-8d41-b283b4f98e53}	220,129883	127,3581
39	Polygon	47	classroom	tall and Long	Learner1	Female	{247b7a31-a1f5-4f58-9fda-ccbbd278c332}	1079,069336	166,0753
40	Polygon	48	library	big	Learner1	Female	{855d01e0-76fc-4a13-ae3b-2e4e5d513cb3}	507,619141	89,4547
41	Polygon	49	library	3d	Learner 2	Male	{b57ac57b-b786-4ee9-a90c-27e4672f70c9}	332,257813	89,9398
42	Polygon	50	rusted tanks	was a food shelter(kitchen)			{fccfbb77-abbc-44be-95e5-ed8cf3d3295f}	16,545898	20,3068
43	Polygon	51	container		Learner1	Male	{b119e1fc-969d-49ae-ace0-266a31f7c82e}	39,280273	25,3578
44	Polygon	52	matric bloc	matuf	Learner2	Female	{27abc339-3dea-4f9c-840d-a48793819628}	201,396484	54,3737
45	Polygon	53	matric block	grade 11	Learner1	Female	{55793fd1-1af9-4638-8849-237dc7331b46}	127,975586	47,0484

1 (0 out of 110 Selected)

Polygons

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.

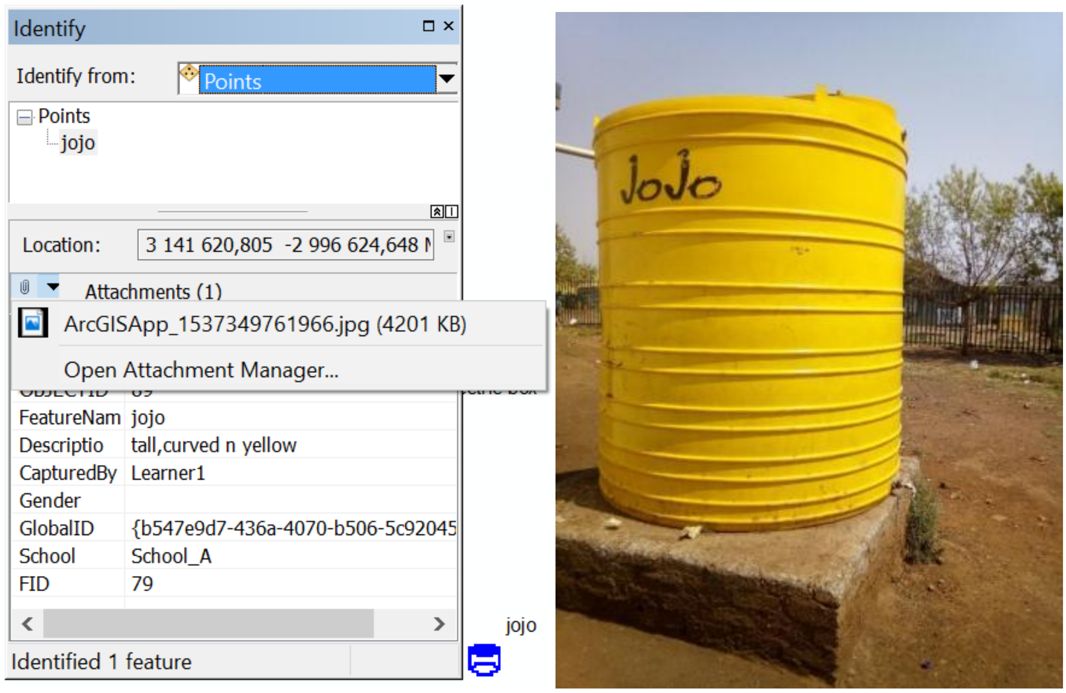


Figure 8: Example of a feature taken in School A

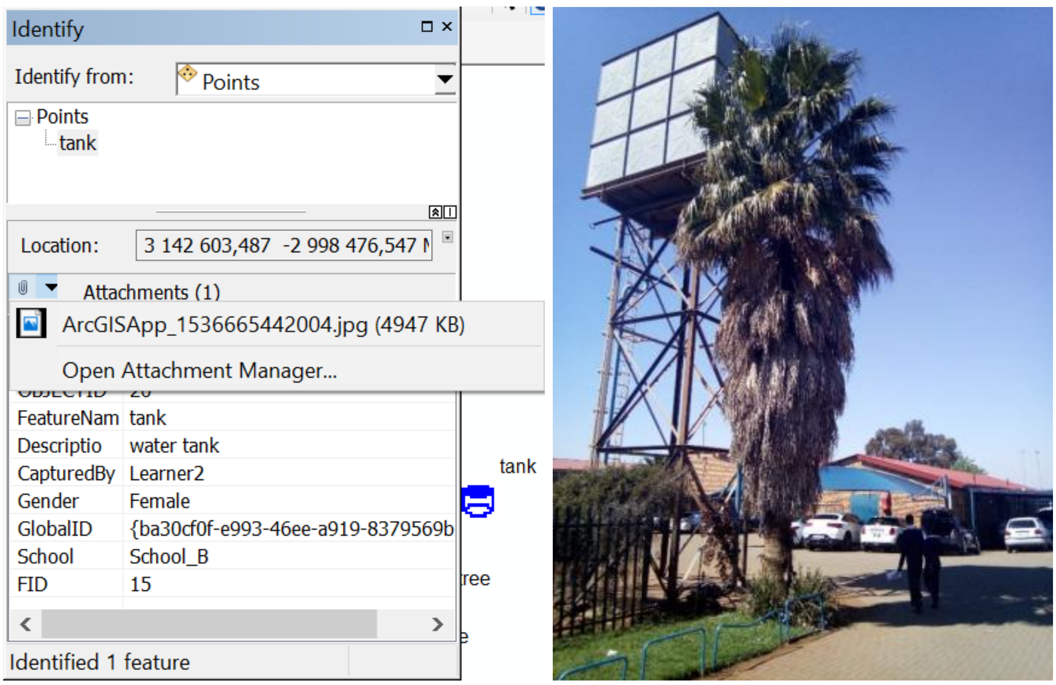


Figure 9: Example of a feature taken in School B

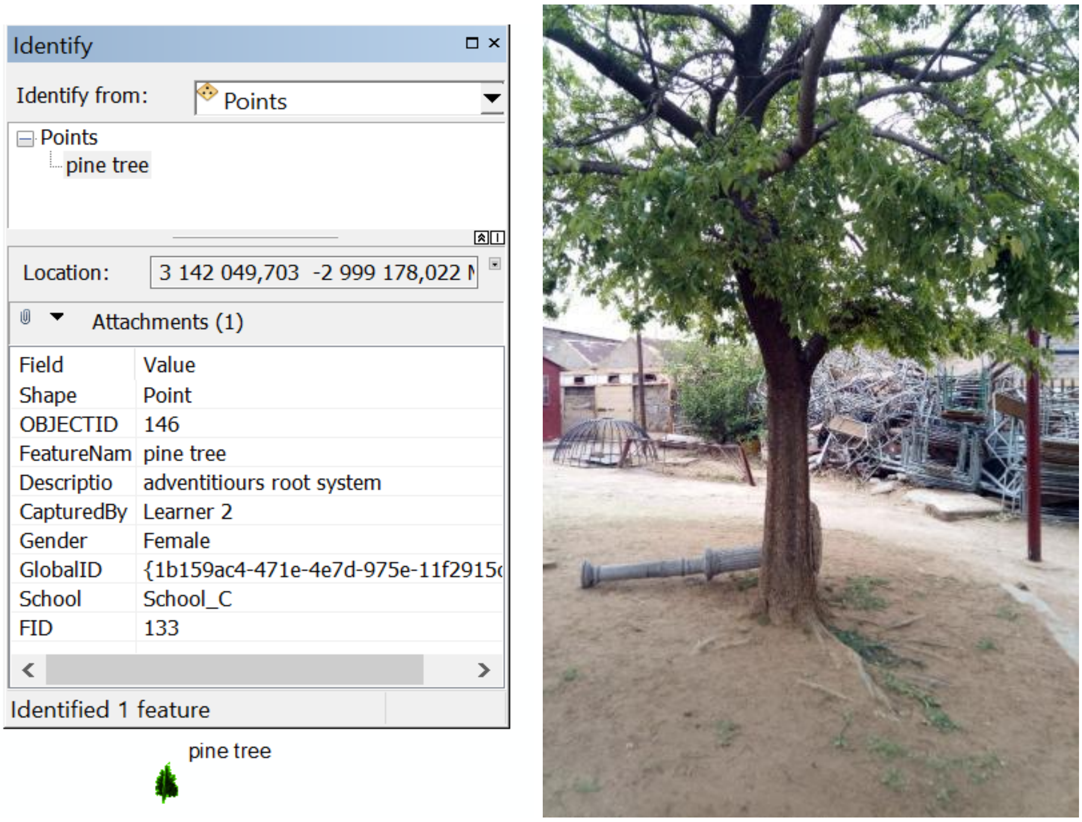


Figure 10: Example of a feature taken in School C

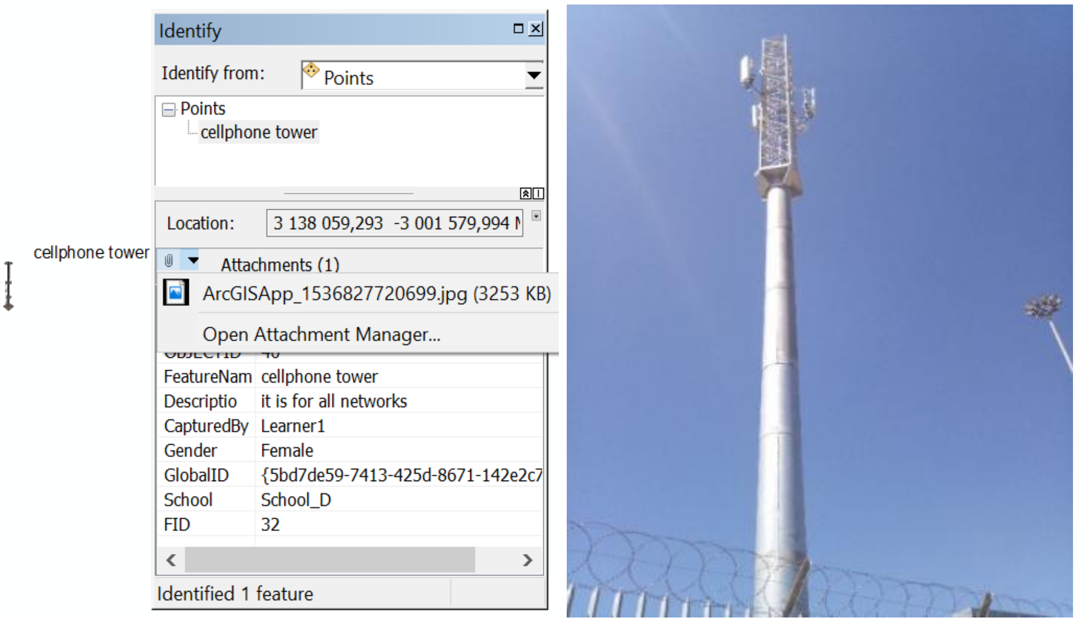


Figure 11: Example of a feature taken in School D

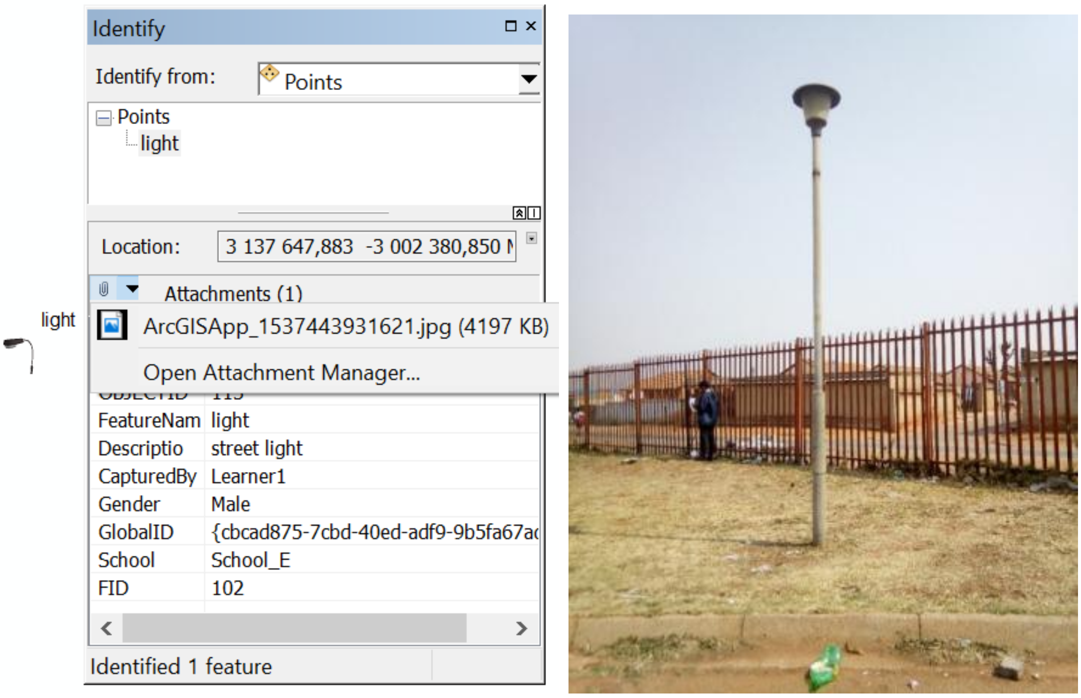


Figure 12: Example of a feature taken in School E

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.

Figure 13: Overview of School A (source: City of Ekurhuleni 2018 imagery)

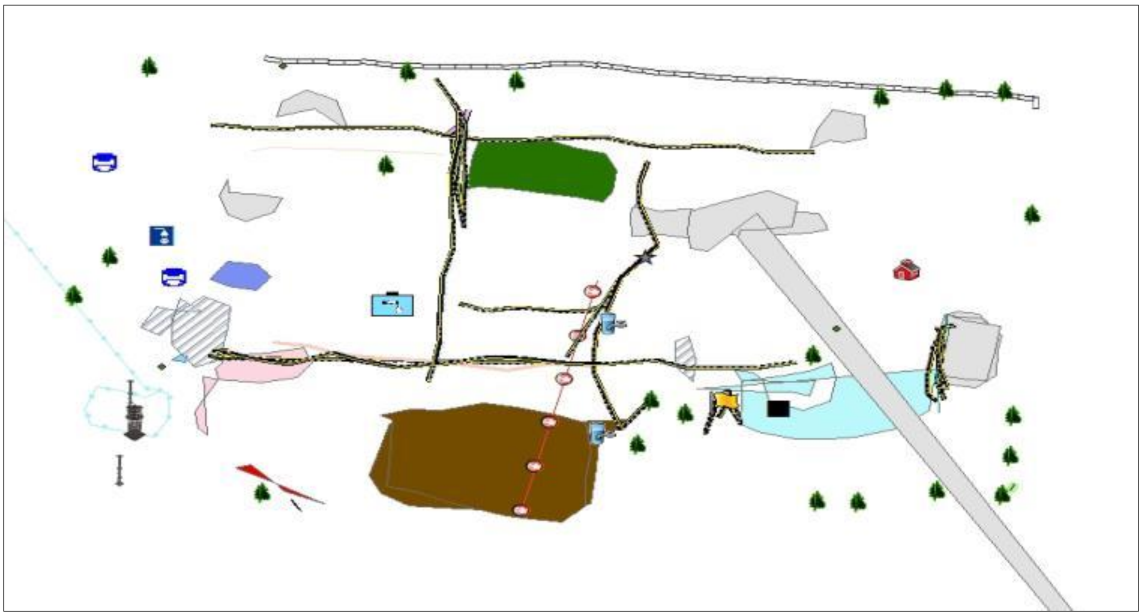


Figure 14: All features collected in School A

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.

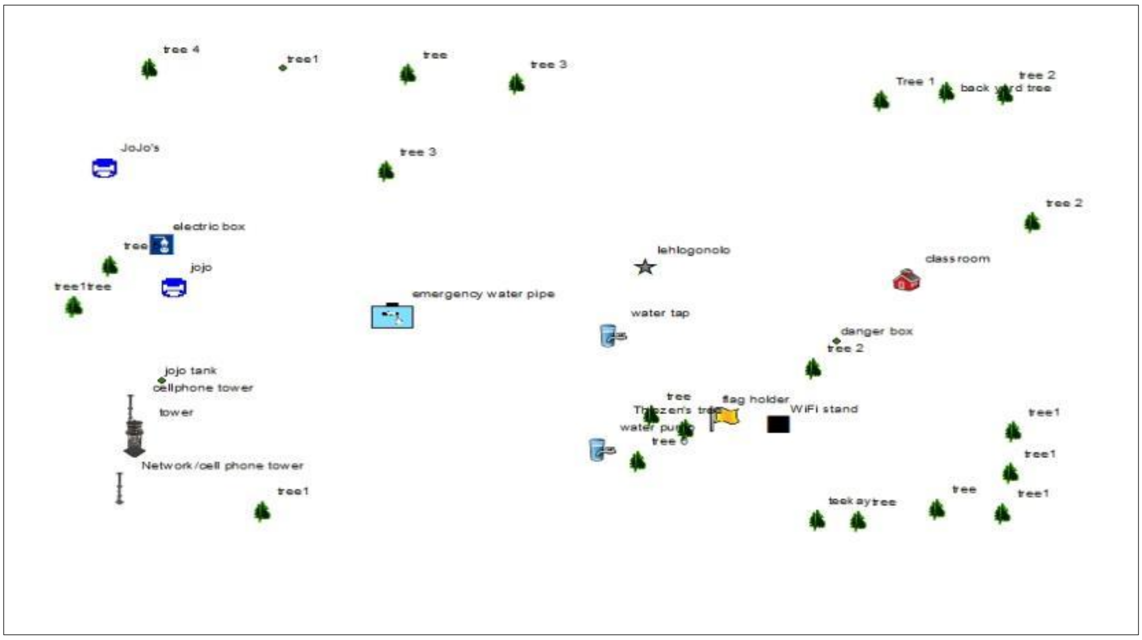


Figure 15*: School A point features*

Table 4: School A point attributes

Table

Points

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	
50	Point	61	leekay	tall and green	Learner1	Male	{5decdbc9-4
51	Point	62	tree1	tall and green	Learner1	Female	{c0d8667f-c
52	Point	63	tree1	tall and green			{6dbdaca6-4
53	Point	64	tree1	tall, green	Learner2	Female	{2c07fc54-8
54	Point	65	tree	tall n green			{b5755fb1-7
55	Point	66	tree1	tall and green	Learner1	Female	{bf3f4248-58
56	Point	67	tree	tall and green	Learner1	Female	{a4aa84c0-1
57	Point	68	tree1	tall,green	Learner1	Female	{a9433cdc-5
58	Point	69	tree	short,green and thin	Learner1	Male	{d687f80c-38
59	Point	70	tree	medium size,thin	Learner 2	Female	{d70837fe-1
60	Point	71	tree 2	thin tall	Learner 2	Female	{c83d455a-7
61	Point	72	back yard tree	tall,thin	Learner1	Female	{fa0390f4-20
62	Point	73	Network/cell phone tower	very tall	Learner1	Female	{91247e0f-3
63	Point	74	flag holder	tall and grey in colour	Learner1	Female	{98069735-e
64	Point	75	lehlogonolo	green,brown,curved	Learner1	Female	{11605cfa-3f
65	Point	76	tree 2	short and green	Learner 2	Female	{df9f5820-74
66	Point	77	jojo tank	medium tall, wide	Learner 2	Female	{2c0c9087-4
67	Point	78	Tree 1	slim n green	Learner1	Female	{b51be16e-2
68	Point	79	tree 2	slim and short	Learner 2	Male	{8c5898c3-4f
69	Point	80	water pump	short ,yellow and red in colour	Learner1	Female	{a03b296c-0
70	Point	81	tree 3	slim curved and green	Learner 2	Male	{a8f555fe-66
71	Point	82	tree	tall and green	Learner1	Male	{a03dcde4-1
72	Point	83	tree 4	half,green and brown	Learner 2	Male	{64cb9e7e-4
73	Point	84	tree1	tall and green	Learner1	Male	{1bf9e715-e
74	Point	85	classroom	white	Learner 2	Male	{6228267e-0
75	Point	86	cellphone tower	tall	Learner 2	Female	{d4649afe-4
76	Point	87	electric box	short and green	Learner1	Female	{003d6a67-1
77	Point	88	tree 3	long an leaveless	Learner1	Female	{dfc234d4-f9
78	Point	89	jojo	tall,curved n yellow	Learner1		{b547e9d7-4
79	Point	90	JoJo's	big and green	Learner 2	Male	{2e218bbc-e
80	Point	91	emergency water pipe	red,round(folded)	Learner1	Female	{229772ff-22
81	Point	92	tree 5	short and burnt	Learner 2	Male	{627cd4df-c
82	Point	93	water tap	4 taps and long pipe	Learner 2	Female	{f456e52c-e
83	Point	94	tower	tall and silver	Learner 2	Male	{ce683847-2
84	Point	95	Thipzen's tree	very tall with branches	Learner1	Female	{f91ebcf1-12
85	Point	96	WiFi stand	tall and grey in colour	Learner 2	Female	{28142383-
86	Point	97	tree 6	slim and wide	Learner 2	Male	{620427d9-0
87	Point	98	danger box	orange, short	Learner 2	Female	{8b41369b-1

1 (38 out of 142 Selected)

Points

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.

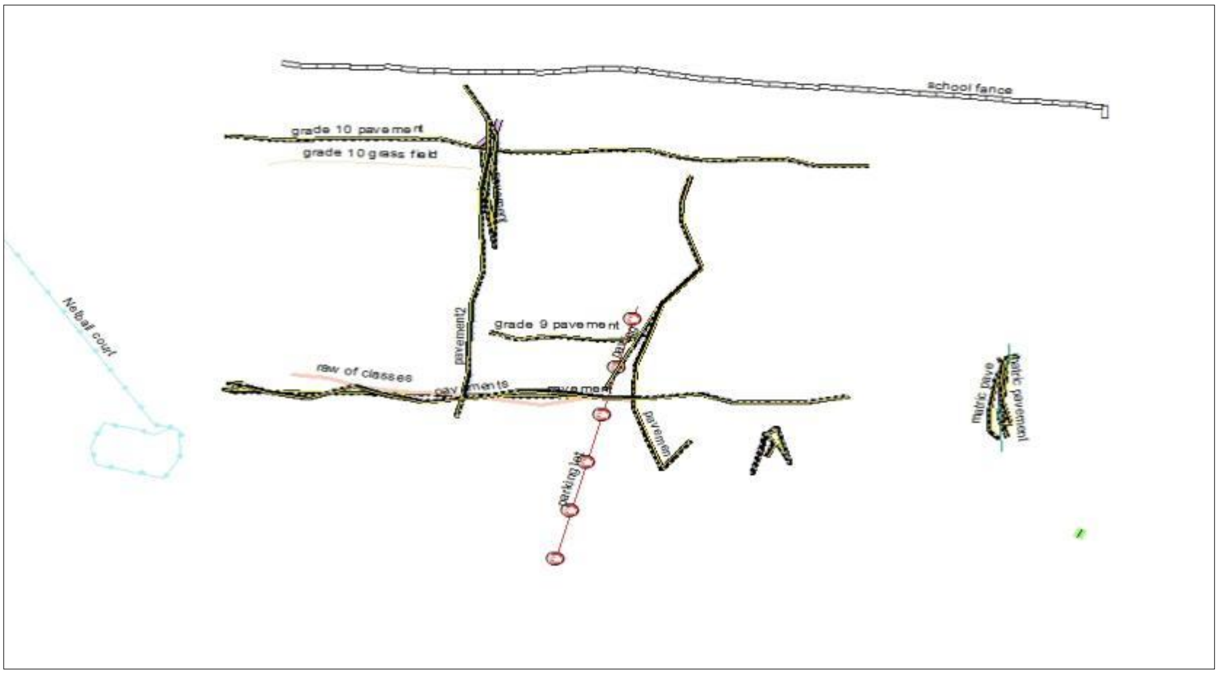
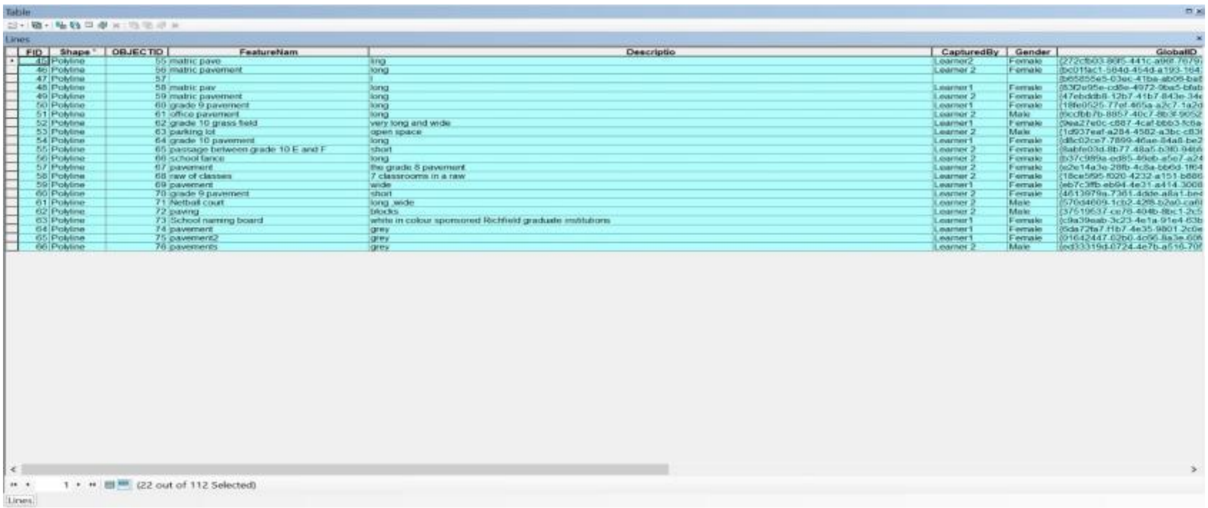


Figure 16: School A line features

Table 5: School A line attributes



Table

Lines

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID
45	Polyline	55	matric pave	lng	Learner2	Female	{272cfb03-8f85-441c-a9f8-7679
46	Polyline	56	matric pavement	long	Learner 2	Female	{bc011ac1-5840-454d-a193-164
47	Polyline	57		l			{b65855e5-03ec-41ba-ab06-ba8
48	Polyline	58	matric pav	long	Learner1	Female	{83f2e95e-cd8e-4972-9ba5-bfab
49	Polyline	59	matric pavement	long	Learner 2	Female	{47ebddb8-12b7-41b7-843e-34e
50	Polyline	60	grade 9 pavement	long	Learner1	Female	{18fe0525-77ef-465a-a2c7-1a2d
51	Polyline	61	office pavement	long	Learner 2	Male	{9ccfbb7b-8857-40c7-8b3f-9052
52	Polyline	62	grade 10 grass field	very long and wide	Learner1	Female	{9ea27e0c-c887-4caf-bbb3-fc6a
53	Polyline	63	parking lot	open space	Learner 2	Male	{1df937eaf-a284-4582-a3bc-c83
54	Polyline	64	grade 10 pavement	long	Learner1	Female	{d8c02ce7-7899-46ae-84a8-be2
55	Polyline	65	passage between grade 10 E and F	short	Learner 2	Female	{9abfe03d-8b77-48a5-b380-94b
56	Polyline	66	school fance	long	Learner 2	Female	{b37c989a-ed85-49eb-a5e7-a24
57	Polyline	67	pavement	the grade 8 pavement	Learner 2	Female	{e2e14a3e-28fb-4c8a-bb6d-1f64
58	Polyline	68	raw of classes	7 classrooms in a raw	Learner 2	Female	{18ce5f95-f020-4232-a151-b886
59	Polyline	69	pavement	wide	Learner1	Female	{eb7c3ffb-eb94-4e31-a414-3008
60	Polyline	70	grade 9 pavement	short	Learner 2	Female	{4613979a-7361-4dde-a8a1-be
61	Polyline	71	Netball court	long ,wide	Learner 2	Male	{570d4609-1cb2-428-b2a0-ca6
62	Polyline	72	paving	blocks	Learner 2	Male	{37519637-ce78-404b-8bc1-2c5
63	Polyline	73	School naming board	white in colour sponsored Richfield graduate institutions	Learner1	Female	{c9a39eab-3c23-4e1a-91e4-63b
64	Polyline	74	pavement	grey	Learner1	Female	{6da72fa7-f1b7-4e35-9801-2c0e
65	Polyline	75	pavement2	grey	Learner1	Female	{91642447-02b0-4c96-8a3e-606
66	Polyline	76	pavements	grey	Learner 2	Male	{ed33319d-0724-4e7b-a516-70f

1 (22 out of 112 Selected)

Lines

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.

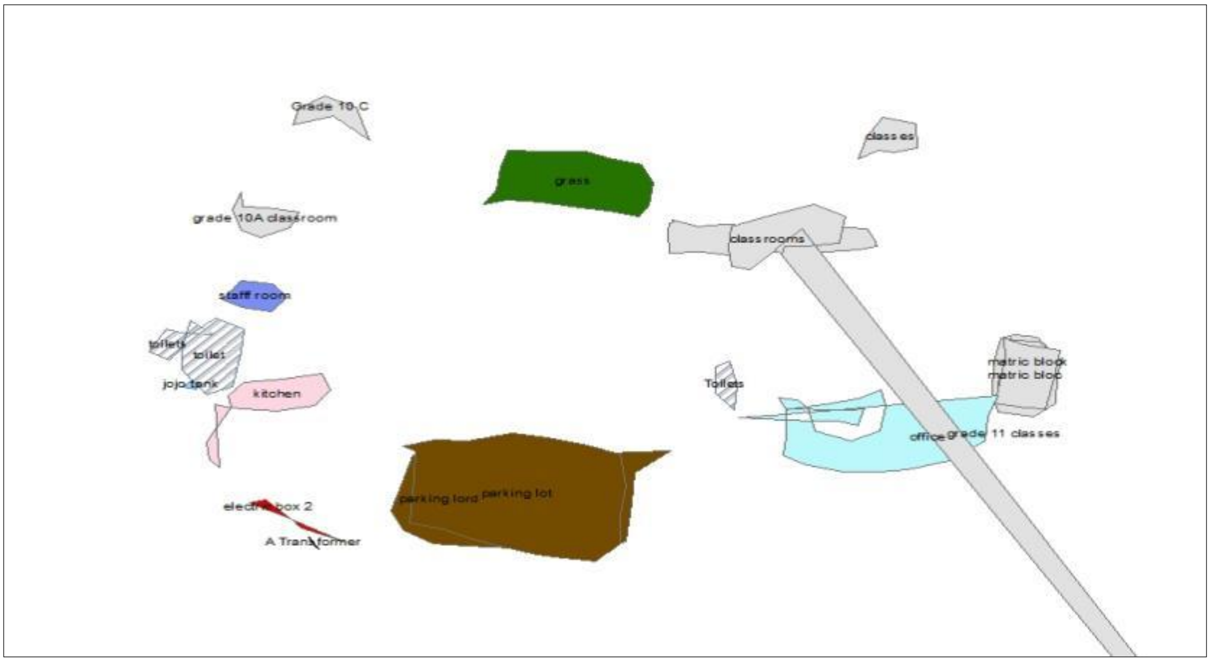


Figure 17: School A polygon features

Table 6: School A polygon attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID	Shape__Are	Shape__Len
44	Polygon	52	matric bloc	mafuf	Learner2	Female	{27abc339-3dea-4f6c-840d-a46793819628}	201,396484	54,373785
45	Polygon	53	matric block	grade 11	Learner1	Female	{55793f01-1af9-4638-8849-237dc7331b46}	127,975586	47,048448
46	Polygon	54	matric block	rectangular	Learner 2	Male	{342095fc-5108-4d5e-bfee-ee570cdf32da}	1,301758	5,586515
47	Polygon	55	matric block	rectangular shape	Learner1	Female	{632c3900-a262-4142-a65e-0e1643728401}	143,09668	49,665562
48	Polygon	56	parking lord	rectangular in shape	Learner 2	Female	{47c86533-aae5-47f3-a179-7bbfbb05075c}	955,900391	133,873083
49	Polygon	57	staff room	cubic,long	Learner1	Male	{95cb092b-1f46-40e7-9200-4c190ed2a8bf}	56,977539	29,880646
50	Polygon	58	office	blocks	Learner1	Female	{5dc8df32-cdf6-4a4a-9f6a-6d13ffaffa79}	513,275391	206,469223
51	Polygon	59	Grade 10 C	cubic	Learner1	Female	{757acd87-aec8-43b9-a85d-2a71f0bbf4ac}	57,993164	41,273657
52	Polygon	60	grade 10A classroom	rectangular shape	Learner 2	Female	{e002f727-8d00-4c8c-b250-7a4bb8b232e9}	64,463867	37,381136
53	Polygon	61	jojo tank	cylindrical and yellow in colour	Learner1	Female	{12418278-1821-40c7-9876-a9d815678ab4}	4,194336	9,825938
54	Polygon	62	classes	rectangular	Learner1	Female	{f50ff8fa-17e8-4161-a3bc-130befe0dfb4}	66,760742	34,975085
55	Polygon	63	classrooms	rectangular	Learner 2	Female	{9accbc35-3a5e-4b12-9620-164c6043b21a}	243,800781	88,156921
56	Polygon	64	parking lot	very big, large	Learner 2	Female	{9f58a982-63ec-48c8-804f-868c84ebf5be}	970,585938	124,315934
57	Polygon	65	A Transformer	rectangular prism shape	Learner1	Female	{34064057-1b23-4316-b265-f5d68dfe4e6d}	0,479492	7,258149
58	Polygon	66	toilets	rectangular	Learner 2	Female	{5126b607-7c38-491b-a715-dbfd5f2fa1c1}	38,073242	35,735167
59	Polygon	67	grass	rectangular shape	Learner1	Female	{bcbdf9c7a-468c-4fe4-a2d0-ec88ffa92211}	349,085938	81,971769
60	Polygon	68	kitchen	long,wide	Learner1	Male	{d0279530-65fb-4f40-ac9c-76fcd9770a8a}	141,880859	80,594094
61	Polygon	69	electric box 2	big,short and green	Learner 2	Male	{d0980b83-a517-4bf5-b81e-8f4f91cd0a2}	13,208008	39,989247
62	Polygon	70	grade 11 classes	blocs	Learner 2	Female	{f8274f6ad-3b14-4ac6-b08c-0a9a9a9947a4}	1087,535156	631,574084
63	Polygon	71	Toilets	male and female teachers toilets	Learner1	Female	{80332970-a383-472f-8a4a-11b92ef1536c}	31,514648	26,155032
64	Polygon	72	toilet	white	Learner1	Female	{b5e8bc45-11b9-48cd-bd54-2b0758df773}	152,765625	47,806763

(21 out of 110 Selected)

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)

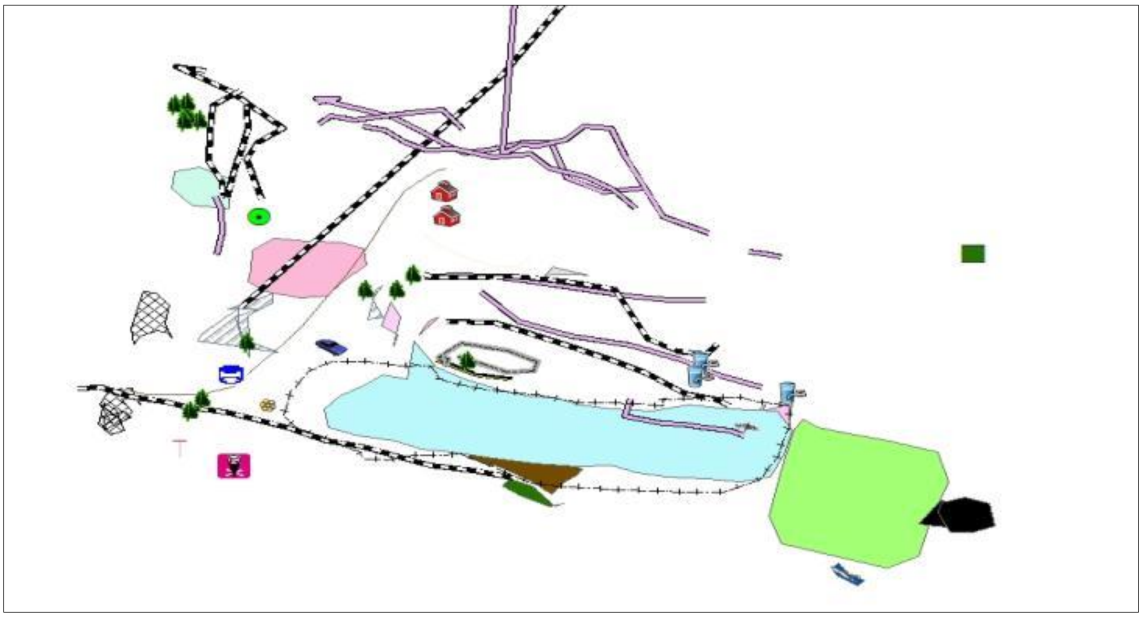


Figure 19*: All features captured in School B*

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.

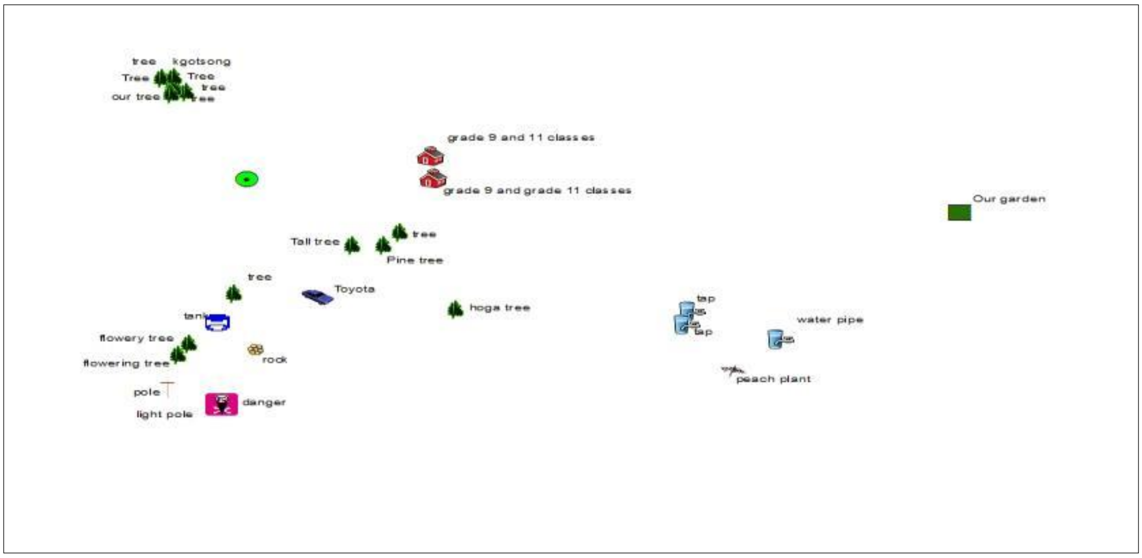


Figure 20: School B point features

Table 7: School B point attributes

Table

Points

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	
0	Point	5	tree	green tree	Learner1	Male	{af832388-4
1	Point	7	tree	short one	Learner1	Male	{250a9a98-f
2	Point	8	tree	green tree	Learner1	Male	{d2e56b45-a
3	Point	9	Tree	green tree	Learner1	Male	{808c0902-b
4	Point	10	our tree	green tree	Learner1	Female	{52b23c04-1
5	Point	11	kgotsong	black tea	Learner1	Female	{72d72b15-6
6	Point	12	Tree	Green tree	Learner1	Female	{18e45014-4
7	Point	13	flowery tree	green leaves and pink flowers	Learner1	Female	{b978ef2e-8
8	Point	14	Tall tree	golden green leaves	Learner 2	Female	{084e00c8-b
9	Point	15	tree	tall	Learner1	Male	{b89e7b1-e
10	Point	16	Toyota	blue car	Learner1	Male	{28559ae6-b
11	Point	17	flowering tree	green leaves and pink flowers	Learner1	Female	{6d84362a-e
12	Point	18	rock	big and brown	Learner1	Female	{b3638c78-2
13	Point	19	Pine tree	Green and short	Learner1	Male	{7f47f653-4d
14	Point	20	tank	water tank	Learner2	Female	{ba30cf0f-e9
15	Point	21	tap	metal	Learner1	Male	{a55ab6bb-5
16	Point	22	Our garden	cultivation (spinach)	Learner1	Female	{cb95341d-9
17	Point	23	hoga tree	short	Learner1	Female	{2e09c9b4-4
18	Point	24	tap	water resource	Learner 2	Female	{b836cdd2-1
19	Point	25	water pipe	Grey & round	Learner 2	Female	{890cf981-a
20	Point	26	tree	green tree	Learner1	Male	{41a3ddab-7
21	Point	27					{c1a972c1-a
22	Point	28	grade 9 and 11 classes	double store building	Learner 2	Male	{4ce7625e-1
23	Point	29	peach plant	Green leaves with pink flowers	Learner 2	Female	{71f9a58a-a
24	Point	30	grade 9 and grade 11 classes	double store building	Learner 2	Male	{34cb90f5-d
25	Point	31	pole	white	Learner2	Female	{26afb4e7-4-
26	Point	32	danger	still made danger	Learner 2	Female	{36cb228b-c
27	Point	33	light pole	tall	Learner1	Male	{73057877-a

(28 out of 142 Selected)

Points

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.

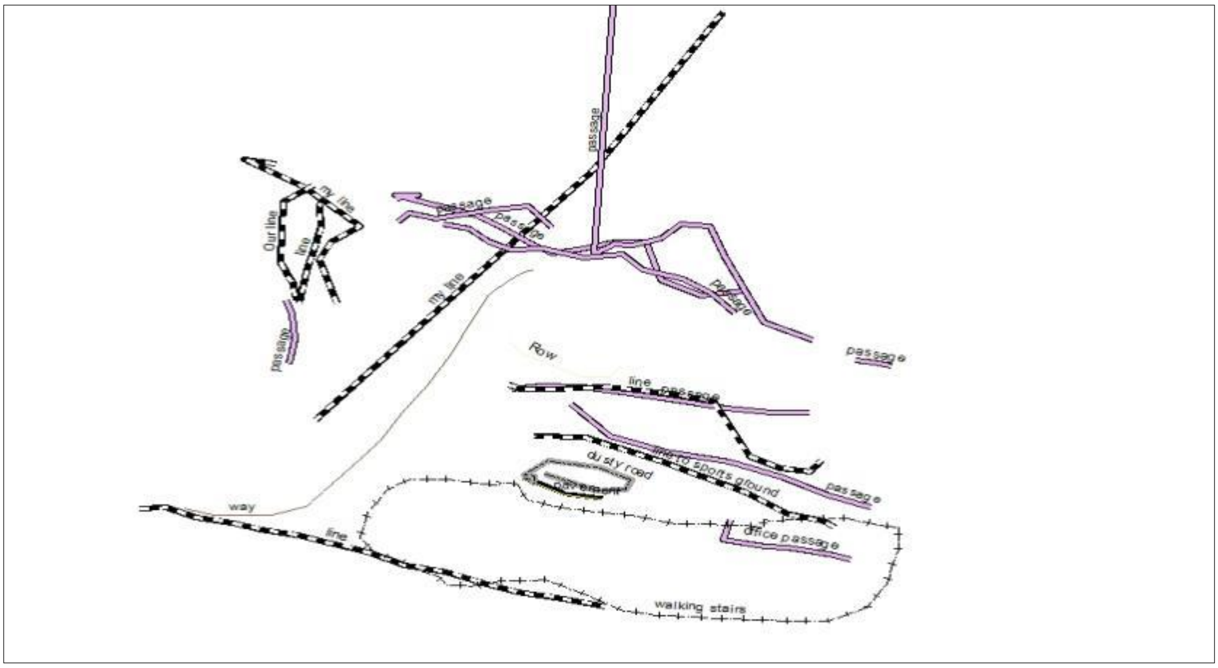


Figure 21: School B line features

Table 8: School B line attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID
0	Polyline	6	line	long	Learner1	Male	{57d1cc4c-0583-4542-9083-30e
1	Polyline	8	my line	side walk	Learner 2	Female	{aeaafcce-d777-4043-b3a1-786
2	Polyline	9	Our line	long and wide	Learner1	Female	{d232eb7e-0fd6-45e2-9e18-d7e
3	Polyline	10	passage	paving	Learner1	Female	{dfc89780-f643-4cd5-9a67-578
4	Polyline	11	my line	karmak	Learner 2	Female	{a6bc0a17-01d2-4d11-bae2-952
5	Polyline	13	Row	water row	Learner1	Male	{4e134399-d6cb-4d84-b046-048
6	Polyline	14	line	long entrance	Learner 2	Female	{30929c93-45d4-4e2a-8kdd-2e8
7	Polyline	15	passage	long	Learner1	Male	{36100dca-999a-468f-b100-97e
8	Polyline	16	office passage	pavement	Learner1	Male	{1dcf37e3-e36f-4ae3-8e56-1335
9	Polyline	17	passage	it is thin and it is between two staff rooms	Learner 2	Female	{2318ecb1-b6f3-4036-b72c-802
10	Polyline	18	pavement	brick layered	Learner1	Male	{9bf72ded-4a2a-41b3-a9eb-63e
11	Polyline	19	walking stairs	brownish tiles	Learner1	Female	{c9a2f58-a743-4ff7-ab91-ffec3
12	Polyline	20	passage	long line	Learner2	Female	{9e543245-9c23-479a-887a-3ac
13	Polyline	21	line	long way	Learner1	Female	{a428ba5c-db4b-43de-861d-94
14	Polyline	22	passage	long and wide	Learner1	Female	{015d027c-45f4-4bfa-aa45-e5d
15	Polyline	23	passage	long line	Learner 2	Female	{c921a5e3-514f-4772-aa1e-4d
16	Polyline	24	passage	short & narrow	Learner 2	Female	{c63c12b2-5533-4499-b463-e4b
17	Polyline	25	passage	long line	Learner1	Male	{4cd59231-493d-4536-a206-921
18	Polyline	26	way	from the classes to the gate	Learner1	Male	{8e9b968f-4956-45a8-b97d-52
19	Polyline	27	line to sports ground	Pavement	Learner 2	Female	{a423a1bd-0641-47fc-99eb-74a
20	Polyline	28	dusty road	dry grassy like walking path	Learner 2	Male	{391f1295-a434-4eae-ae88-789

(21 out of 112 Selected)

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.

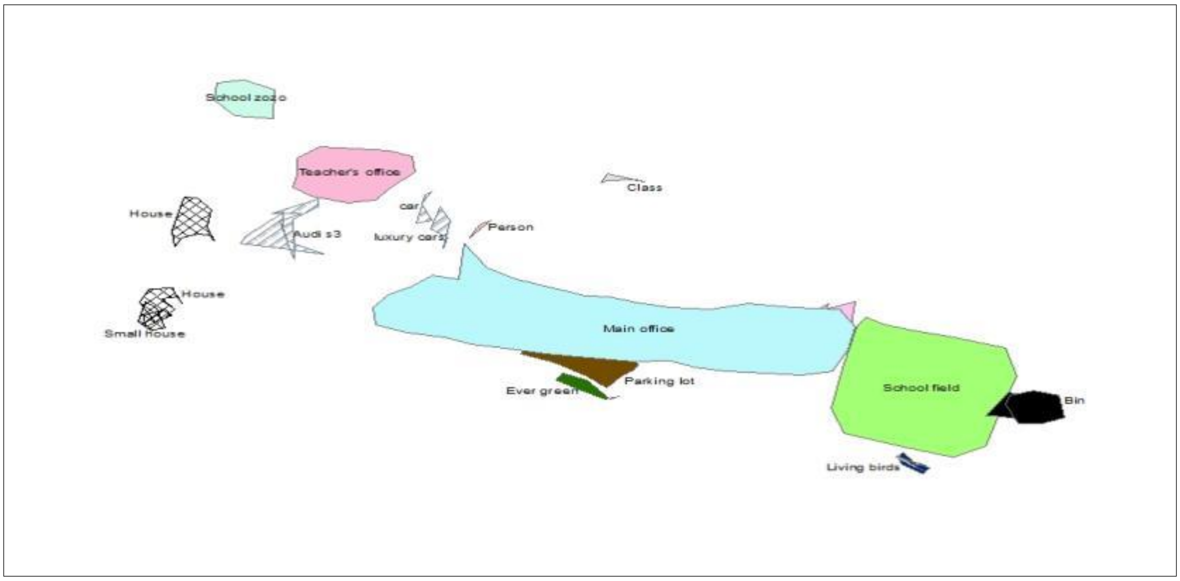


Figure 22: School B polygon features

Table 9: School B polygon attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID	Shape__Are	Shape__Len
0	Polygon	7	audi s3	orange	Learner1	Male	{a4688966-fced-4b00-976e-e833d76a57d6}	80,144531	92,821931
1	Polygon	8	car	white Chevrolet	Learner1	Male	{622492ae-a7b1-41b5-b9d8-0dad342d88bf}	8,074219	21,55901
2	Polygon	9	school zozo	big	Learner1	Male	{471a40c8-f854-47e3-8819-14916224b701}	92,544922	36,890417
3	Polygon	10	library	white container	Learner2	Female	{69969834-5b0f-41ec-a9f9-8e72a61dee59}	46,396484	33,263929
4	Polygon	11	house	brown	Learner 2	Female	{22abc121-0511-4d77-a3c1-dd2a36968380}	38,296875	33,173105
5	Polygon	12	school field	netball court	Learner1	Male	{5901d384-f979-4282-a710-eac1ca669746}	947,618164	117,260765
6	Polygon	13	luxury cars	blue isuzu	Learner1	Female	{6c2d8faa-885d-4d9e-8eb1-01e94ddedf69}	16,911133	25,200701
7	Polygon	14	library	white container	Learner1	Male	{525c9ae0-b3b8-403c-a316-76b0a021de66}	88,858398	53,909496
8	Polygon	15	bin	big yellow and dirty	Learner1	Female	{964bdf9d-0a69-47e5-8069-018d964d9f74}	62,578125	32,729405
9	Polygon	16	class	short	Learner1	Female	{9c0ba478-897d-4af4-b49f-cc0dc3d69afd}	6,586914	18,326136
10	Polygon	17	ever green	container	Learner1	Male	{dadaaab3-0a40-465f-a7d9-0a90f867dbe6}	24,59082	28,937898
11	Polygon	18	bin	big yellow and dirty	Learner1	Female	{112ae2bc-e2ed-4482-ada5-90bccab29d34}	77,665039	33,230871
12	Polygon	19	house	brown	Learner2	Female	{09fc00f6-cab4-4ab7-b59c-e39e68c6c8fe}	61,503906	38,689472
13	Polygon	20	House	security house	Learner 2	Female	{278646ef-30d6-4a19-9b9a-8bf8c112ff87}	12,657227	15,512395
14	Polygon	21	parking lot	long	Learner 2	Female	{3d85530f-cc11-4669-b4f3-3ed53b7753a6}	153,494141	54,338676
15	Polygon	22	main office	building	Learner1	Female	{2d41bcdb-276a-45e6-b2c7-df4effa22a42}	1515,936523	217,133575
16	Polygon	23	small house	near the gate	Learner1	Male	{26294b3d-bba9-418d-842c-09747bb69feb}	23,515625	20,386334
17	Polygon	24	person	tall and dark	Learner 2	Female	{da00b54c-820c-4487-83f3-b9348ec611bc}	2,642578	12,199021
18	Polygon	25	teacher's office	container	Learner 2	Male	{0ce2acb6-1961-4f11-af6-9633479a1ab6}	267,445313	62,891428
19	Polygon	26	living birds	brown and black birds	Learner 2	Male	{10127c5d-8a1d-44ee-a185-13d99068e9c8}	9,725586	42,325408

(20 out of 110 Selected)

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.

Figure 23: School C premises (source: City of Ekurhuleni 2018 imagery)

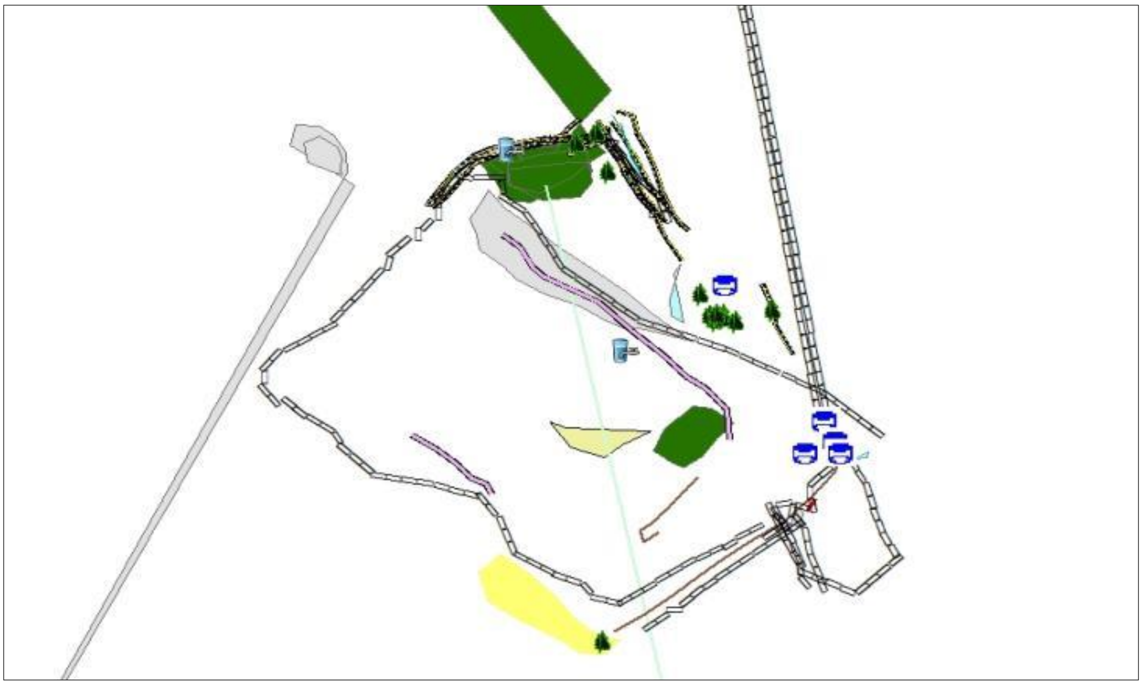


Figure 24: All features captured in School C

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.

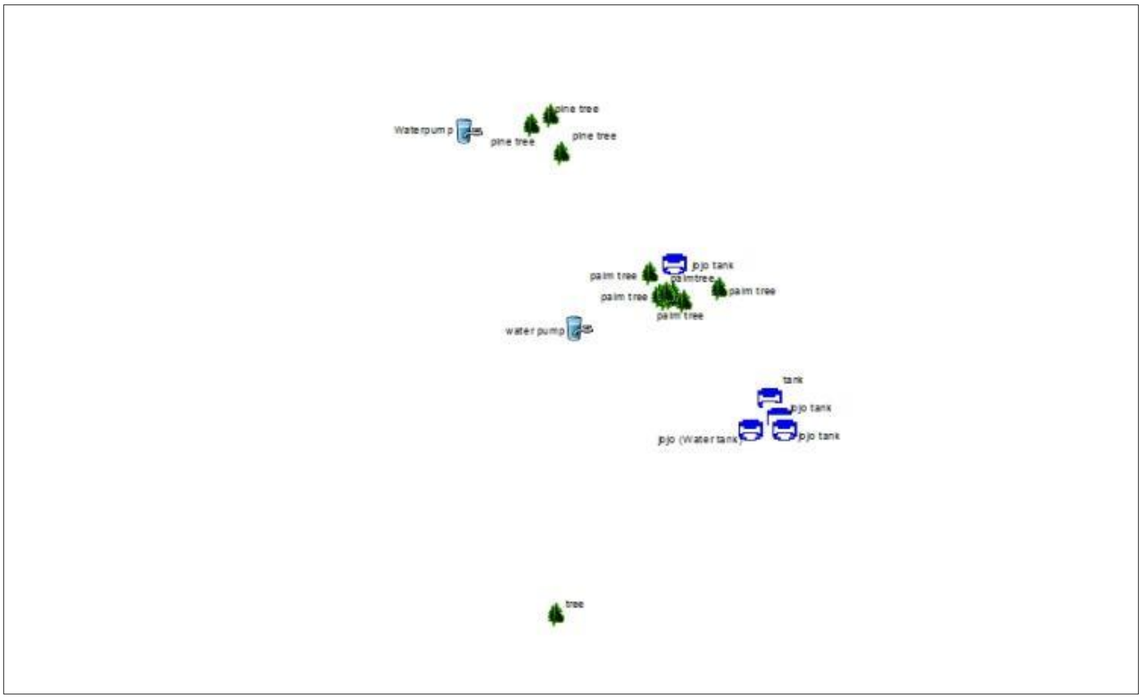


Figure 25: School C point features

Table 10: School C point attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	
122	Point	135	palm tree	big	Learner1	Male	{bbc6226b-3
123	Point	136	palm tree	tall	Learner 2	Male	{0d0a5bdf-8
124	Point	137	palm tree	big	Learner1	Female	{f5986eda-1
125	Point	138	palmtree	big tree	Learner1	Male	{2d152679-2
126	Point	140	palm tree		Learner 2	Male	{763588a-15
127	Point	141	palm tree			Female	{e5f307ca-2
128	Point	142	palm tree	parking	Learner1	Male	{3ec10cda-2
129	Point	143	Waterpump	in front of the row of trees	Learner1	Male	{3bd15838-6
130	Point	144	pine tree	green in colour,adventitious root system	Learner 2	Female	{4508630a-f
131	Point	145	pine tree	green in colour,adventitious root system	Learner 2	Male	{c50d8d73-4
132	Point	146	pine tree	adventitiours root system	Learner 2	Female	{1b159ac4-4
133	Point	147	jojo (Water tank)	Cylindrical and Green	Learner 2	Male	{57583c48-8
134	Point	148	plam	tree	Learner1	Male	{6d2d4814-8
135	Point	149	berry tree	the tree has light green leaves with long stems attached to it and berry fruits all around it	Learner1	Male	{7f4364ec-30
136	Point	150	tank	jojotank	Learner1	Male	{14334538-4
137	Point	151	jojo tank	green,large and filled with water	Learner1	Female	{9a0a25d8-7
138	Point	152	water pump	next to the lawn	Learner 2	Male	{4fed0e08-7
139	Point	153	jojo tank	big and green in colour	Learner1	Female	{f1ded894-5
140	Point	154	jojo tank	green in colour and big in size	Learner 2	Female	{c684f8e0-8
141	Point	155	tree	marulatree	Learner1	Male	{f39d5206-c

(20 out of 142 Selected)

Points

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.

Figure 26: School C line features

Table 11: School C line attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID
89	Polyline	101	pavement	pavement next to a parking car	Learner 2	Female	{5db86477-de00-424f-a160-4eb
90	Polyline	103	pavement	next to the parking	Learner 2	Male	{d16b3ab9-75e1-4226-80fe-862
91	Polyline	104		parking	Learner1	Male	{eeb17629-d66c-4e6a-824a-73
92	Polyline	105	pavement		Learner 2	Male	{c4487607-6129-47f4-85f7-d249
93	Polyline	106	pavement	parking	Learner1	Male	{5e6732b2-91a6-4775-b9f3-997
94	Polyline	107	palm tree				{51c4ed19-7598-41fd-8773-272
95	Polyline	108	pavement	parking	Learner1	Male	{2fce0072-82c1-4bba-b714-eda
96	Polyline	109	fence	large	Learner 2	Male	{d939b4f6-7d64-46e8-a67b-15
97	Polyline	110	Pathway	next to the garden	Learner1	Male	{eeae72af-3218-4990-aea1-ad0
98	Polyline	111	pavement	straight pavement near the staffroom and laboratory room centre	Learner1	Female	{0233c8a7-deb8-409a-a6e8-65
99	Polyline	112	pavement	straight pave near staffroom and laboratory room center	Learner 2	Female	{e5fe6a40-8dd9-46c3-85d3-6c0
100	Polyline	113	pavement	straight pavement	Learner1	Female	{ec633440-1188-43cd-af52-dfed
101	Polyline	115	pavement	concrete coloured driveway near the car parking lot	Learner 2	Male	{996302b2-dfc8-4d9c-894a-67b
102	Polyline	116	fence	school fence	Learner1	Male	{e67f2b9d-473a-4df5-989d-973
103	Polyline	117	fence	line	Learner 2	Male	{9e42123a-7361-4621-aaa1-6b1
104	Polyline	118	wire fence	green	Learner1	Male	{b6c64d9f-b4ad-4d9e-b2e2-5a2
105	Polyline	119	wire fence	green	Learner1	Male	{4a7e5755-2450-490e-b134-60
106	Polyline	120	pathway	next to the lawn and water pump	Learner 2	Male	{198674d2-8bc6-47aa-8942-5d
107	Polyline	121	fance	the fance between the. class rooms and the garden	Learner 2	Male	{72bfcaec-7052-4055-b0ab-30f1
108	Polyline	122	pasage	school path	Learner1	Male	{ef570b41-15a4-4d88-9dc5-df6c
109	Polyline	123	jojo	green tank	Learner 2	Female	{abc2db76-6300-416d-8ec2-14d
110	Polyline	124	school passage	long	Learner 2	Male	{b655ab28-47a0-4196-ba32-834
111	Polyline	125	fence	fence on the garden	Learner1	Male	{330b5839-6423-48de-8374-e4

(23 out of 112 Selected)

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.

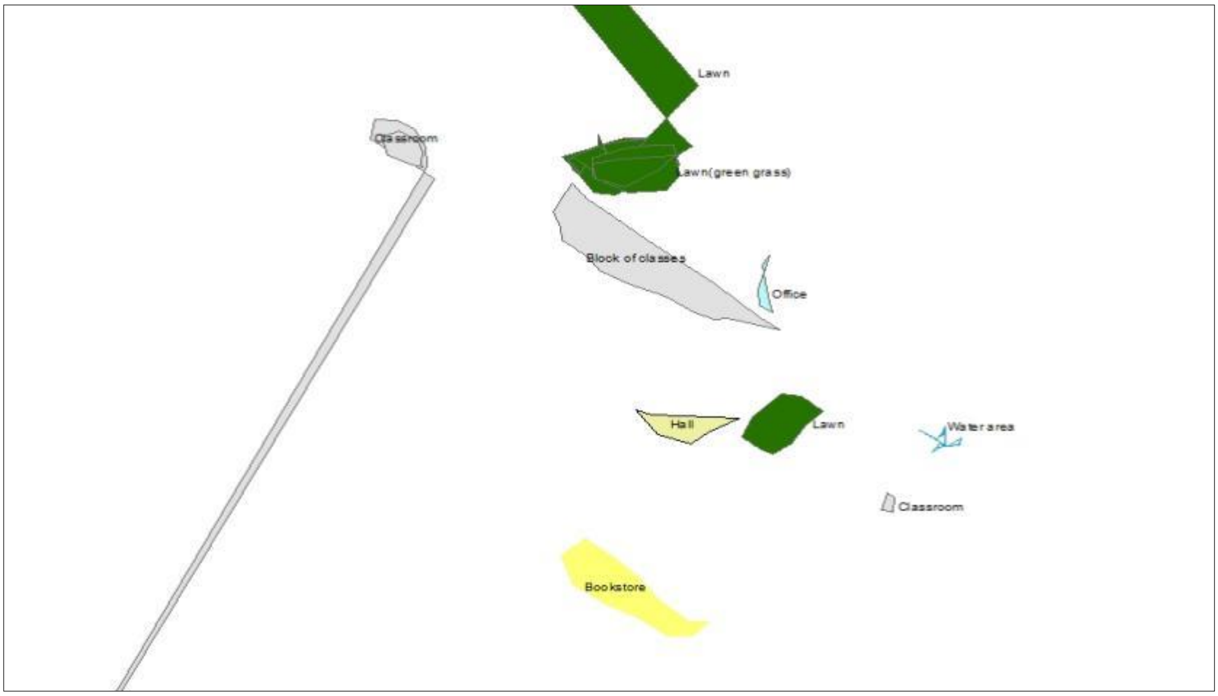


Figure 27: School C polygon features

Table 12: School C polygon attributes

Table

Polygons

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID	Shape__Are	Shape__Len
89	Polygon	98	grass	infront of the office block,green	Learner1	Male	{761e0561-92a2-4f2a-a3d6-eb673446f13b}	265,966797	67,095634
90	Polygon	99	lawn				{0ea3d486-4339-42f5-87b8-9003c8f0ada5}	207,234375	62,594478
91	Polygon	100	grass	green	Learner 2	Male	{b1437d9e-63b7-48b5-a20f-545bd929a4f5}	243,847656	65,987583
92	Polygon	101	grass	in front of the office green in colour	Learner1	Female	{5bee4723-c048-4f02-b7dc-1b164a7173c4}	200,93457	61,13659
93	Polygon	102	grass	in front of the office	Learner1	Male	{a6996ebb-f6dc-40c6-994a-ddffacе78653}	154,036133	49,957944
94	Polygon	103	lawn	near grade 10 classes	Learner1	Male	{203f591a-3001-4f48-86d1-680ea7bcb05c}	165,889648	50,543754
95	Polygon	104	grass	green	Learner1	Male	{3275c0eb-6ff1-4d6f-a3be-be24eb50fa8d}	197,06543	57,968045
96	Polygon	105	grass	green	Learner 2	Male	{7ee1f691-21ef-4263-abef-eec58ba012d3}	2908,950195	1070,294824
97	Polygon	106	grass	greengrass	Learner1	Male	{e3b6ac96-9323-4aad-adb1-4d3789854c6c}	215,71582	56,5425
98	Polygon	107	classroom	maroon shelter	Learner1	Male	{b4821310-f69c-402f-9aba-e0274433bc5d}	487,299805	546,645802
99	Polygon	108	classroom	maroon shelter	Learner 2	Male	{1b2058f2-d516-460b-8835-517361ccb101}	61,469727	31,286212
100	Polygon	109	Block of classes	next to the palm tree	Learner1	Male	{20908262-8582-471e-9954-18ebdb29672c}	581,029297	137,98424
101	Polygon	110	bookstore	building	Learner1	Male	{82c4b4be-998a-49f3-b8ca-87fe4074f4040}	338,407227	92,632697
102	Polygon	111	lawn	next to the pathway and water pump	Learner 2	Male	{217020e3-31af-4b2f-a0a1-694a2bbb5527}	177,170898	52,212114
103	Polygon	112	office		Learner1	Male	{91ecdd4e-4dc4-434f-842e-44873128d01d}	20,71875	35,169974
104	Polygon	113	Hall	building	Learner 2	Female	{1b77216d-d388-4363-b55b-c96e06b7c2ec}	102,220703	53,459458
105	Polygon	114	class room	maroon shelter	Learner1	Female	{402d852a-f6f6-41e9-a382-e7c60faa7aa2}	10,301758	14,107332
106	Polygon	115	lawn(green grass)	a green brown lawn with a green Orange dwarf tree planted on it	Learner1	Male	{eaa62938-4539-4ab9-a3c5-403ced231540}	95,306641	46,830057
107	Polygon	116	water area	rectangular shaped	Learner1	Female	{076305ec-ef2a-40e6-b4d1-454a18a55836}	4,05957	12,611584
108	Polygon	117	water area	rectangular shaped	Learner1	Female	{436adba8-e979-4337-ad22-7a3df101ed04}	5,553711	22,111757
109	Polygon	118	water area	rectangular shap	Learner1	Female	{11bbf95c-937f-45ab-b298-635639a20347}	4,386719	17,703424

1 (21 out of 110 Selected)

Polygons

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)

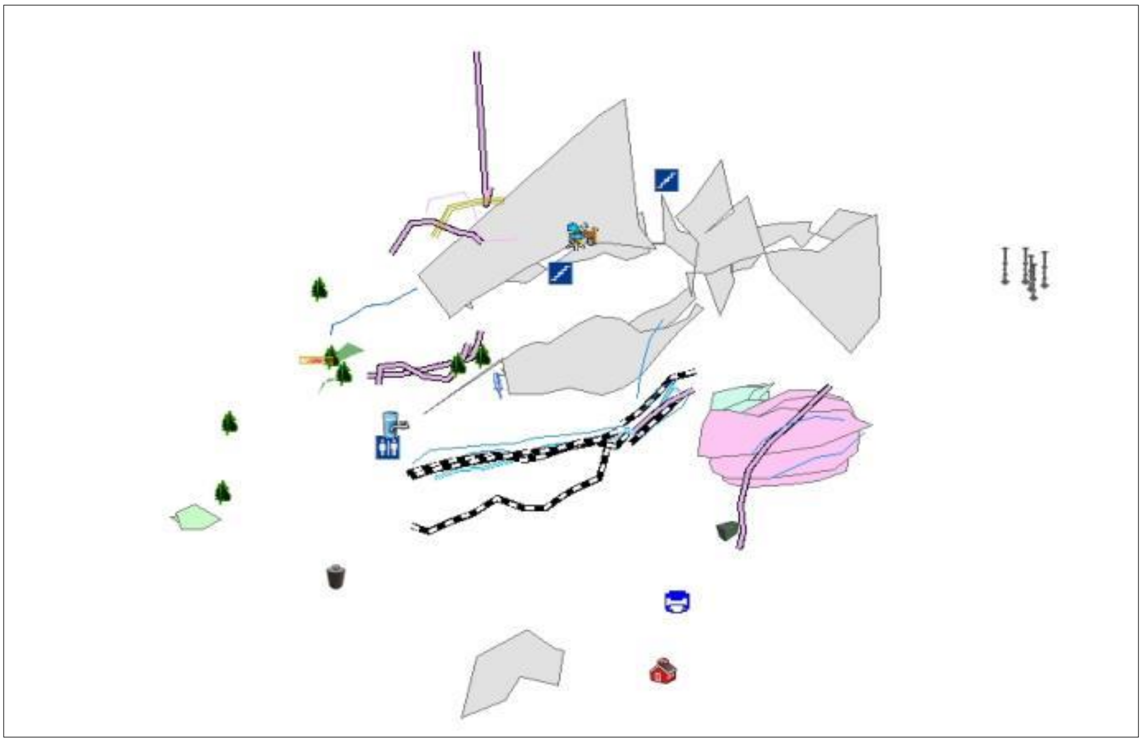


Figure 29: All features captured in School D

Point features

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.

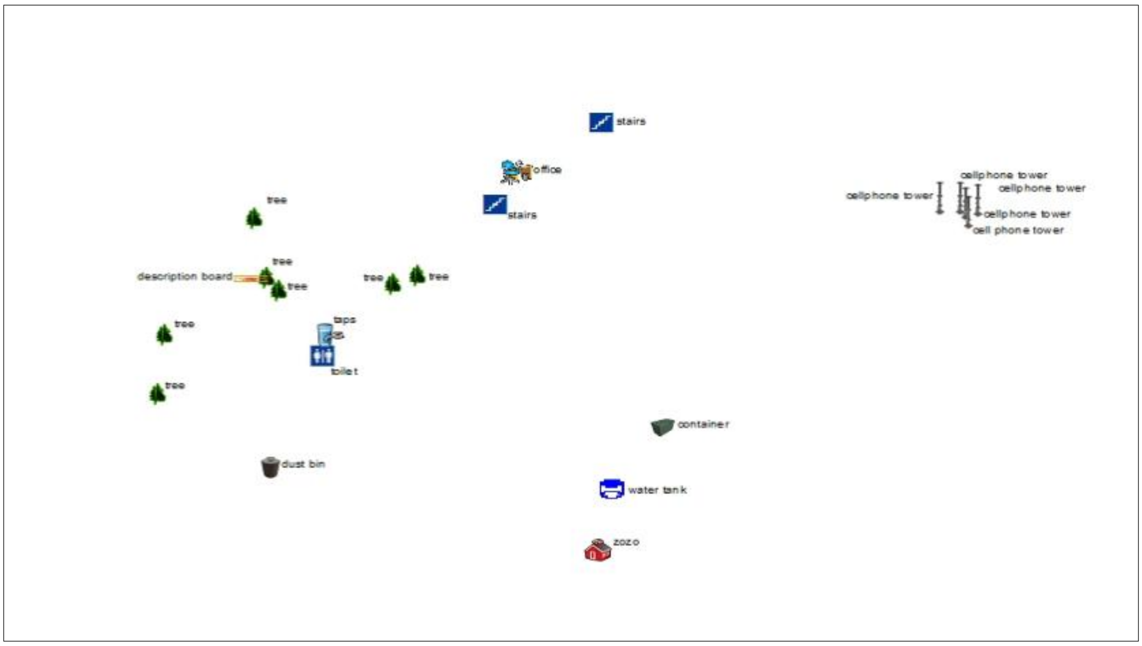
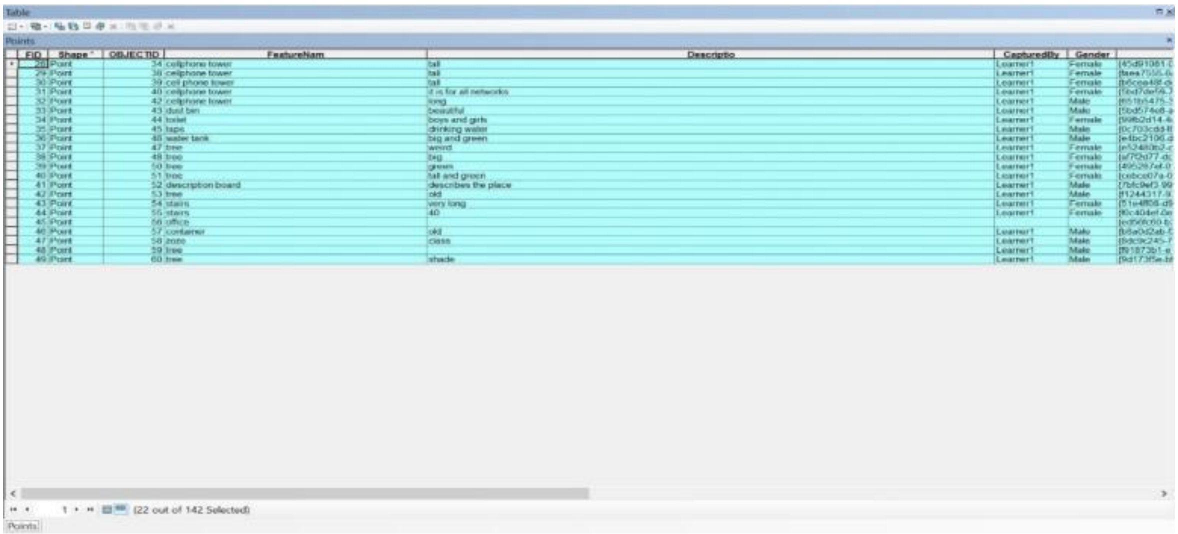


Figure 30: School D point features

Table 13: School D point attributes



FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	
28	Point	34	cellphone tower	tall	Learner1	Female	[illegible]
29	Point	38	cellphone tower	tall	Learner1	Female	[illegible]
30	Point	39	cell phone tower	tall	Learner1	Female	[illegible]
31	Point	40	cellphone tower	it is for all networks	Learner1	Female	[illegible]
32	Point	42	cellphone tower	long	Learner1	Male	[illegible]
33	Point	43	dust bin	beautiful	Learner1	Male	[illegible]
34	Point	44	toilet	boys and girls	Learner1	Female	[illegible]
35	Point	45	taps	drinking water	Learner1	Male	[illegible]
36	Point	46	water tank	big and green	Learner1	Male	[illegible]
37	Point	47	tree	weird	Learner1	Female	[illegible]
38	Point	48	tree	big	Learner1	Female	[illegible]
39	Point	50	tree	green	Learner1	Female	[illegible]
40	Point	51	tree	tall and green	Learner1	Female	[illegible]
41	Point	52	description board	describes the place	Learner1	Male	[illegible]
42	Point	53	tree	old	Learner1	Male	[illegible]
43	Point	54	stairs	very long	Learner1	Female	[illegible]
44	Point	55	stairs	40	Learner1	Female	[illegible]
45	Point	56	office				[illegible]
46	Point	57	container	old	Learner1	Male	[illegible]
47	Point	58	zozo	class	Learner1	Male	[illegible]
48	Point	59	tree		Learner1	Male	[illegible]
49	Point	60	tree	shade	Learner1	Male	[illegible]

(22 out of 142 Selected)

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.

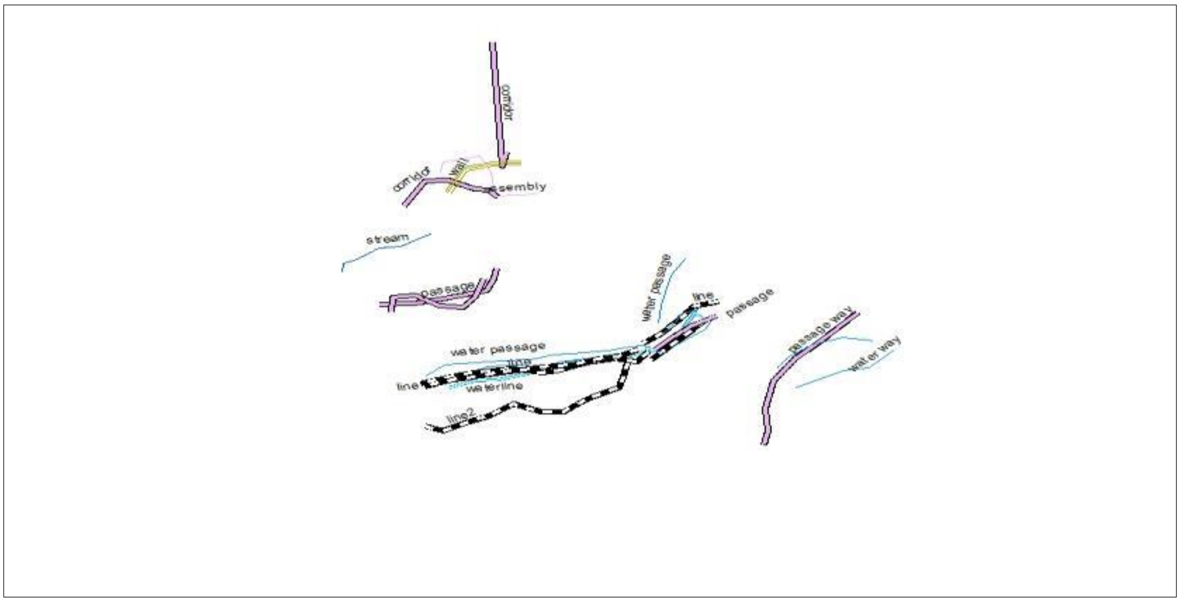


Figure 31: School D line features

Table 14: School D line attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID
21	Polyline	30	line	long	Learner1	Female	{e2a60027-7c3c-4882-af38-649
22	Polyline	31	line	long	Learner1	Female	{cb89fbd9-6a23-41d8-9ed3-2862
23	Polyline	32	water passage	water to pass	Learner1	Male	{1c1fa73b-c09a-4e72-9ed7-803
24	Polyline	33	stream	long			{0b025b5d-1726-4639-b7aa-2b
25	Polyline	34	waterline	Long	Learner1	Female	{b5af42bf-3ea7-4289-85f5-d415
26	Polyline	35	water passage	long	Learner1	Male	{5b2fe3c4-bc1a-4a55-8ce6-177
27	Polyline	36	passage	long	Learner1	Female	{4784ef70-418e-4571-ad2d-350
28	Polyline	37	water passage	long	Learner2	Male	{009ba8b2-724b-42a8-a47c-1b1
29	Polyline	38	water passage	water passes	Learner1	Male	{92dfa27c-b927-497b-aa61-a0e
30	Polyline	39	water passage	long	Learner1	Female	{e037eab9-3b8d-41d2-adf2-754
31	Polyline	40	waterline	long	Learner1	Female	{60fe2d55-c00d-42ad-8f7a-38b0
32	Polyline	41	line2	long	Learner1	Female	{63cbd3d1-498f-4069-8d11-644
33	Polyline	42	line	long	Learner1	Female	{f0aea815-1b79-40cd-b807-062
34	Polyline	43	line	long	Learner1	Female	{903b3dcf-9ea8-4bc9-9458-026
35	Polyline	44	corridor	long	Learner 2	Female	{90143cb7-ff40-431e-a731-8d8a
36	Polyline	46	passage way	long	Learner1	Male	{00fdf34e-9e8c-4a1b-9cc1-12b9
37	Polyline	47	passage	long	Learner1	Female	{a59593b2-aa18-41fe-90b0-cbb
38	Polyline	48	passage l	long	Learner1	Female	{5f845f42-17d9-46a3-857b-c41
39	Polyline	49	corridor	passage	Learner1	Male	{83b94810-d541-450c-881a-195
40	Polyline	50	wall	grey	Learner1	Female	{70a90614-1974-4e98-9ac6-cd2
41	Polyline	51	assembly	bricked	Learner1	Female	{e37a5a85-2815-49b9-bab0-aac
42	Polyline	52	water way	watery	Learner1	Male	{5fbe8c89-dcca-4ae7-a12b-d75
43	Polyline	53	water passage	water passes	Learner1	Male	{f25e63c7-db3c-4c0a-a6ec-61d
44	Polyline	54	stream		Learner1	Male	{10694385-251c-49e6-a4a3-39c

(24 out of 112 Selected)

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.

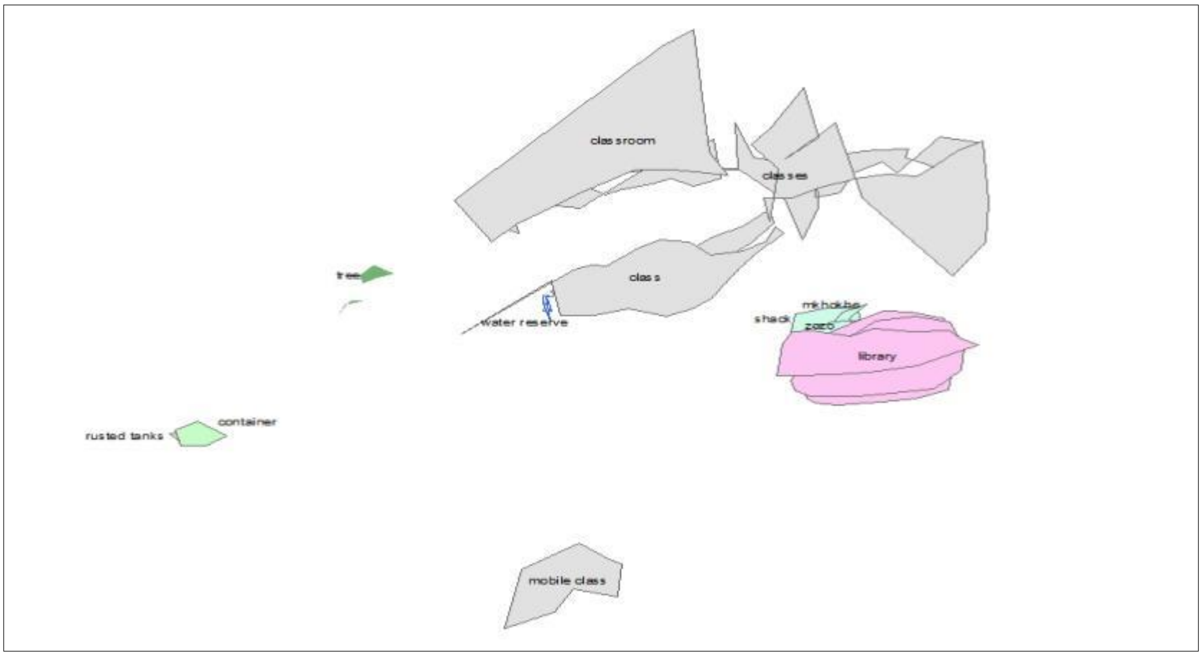


Figure 32: School D polygon features

Table 15: School D polygon attributes

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID	Shape__Are	Shape__Len
20	Polygon	28	mkhokho	made of metal and cubic			{b0b6514c-f65a-46ed-a009-5e77f2dc9206}	47,25	33,414396
21	Polygon	29	zozo	short	Learner1	Female	{e9f1e4b5-bada-4609-a4bb-e1070bfa22c0}	50,026367	29,922698
22	Polygon	30	zozo	3d	Learner1	Male	{1edfce35-0dda-4650-9e13-e5e6dac72290}	41,444336	27,055654
23	Polygon	31	zozo	cubic	Learner1	Female	{61dc70cf-ae7a-44e2-8c28-2c9c8e30577e}	59,257813	30,700638
24	Polygon	32	zozo	iron	Learner1	Female	{eab76a4e-a8b8-4bf8-bde4-8ff318bfcd07}	102,255859	41,904117
25	Polygon	33	shack	store room	Learner 2	Male	{b2866314-400d-47f0-a0bd-b574fe963a61}	13,063477	19,327862
26	Polygon	34	shack	stores furniture	Learner1	Male	{e6aa1311-c104-4778-b906-f3b6a409e645}	52	29,99541
27	Polygon	35	mobile class	learning room	Learner1	Male	{a59d5a53-4ca5-489e-ae5a-0ee5abb6a8a4}	248,775391	72,31464
28	Polygon	36	tree	big	Learner1	Female	{c539194d-33b7-4281-b819-ba4a385b8865}	14,899414	17,058576
29	Polygon	37	tree	weird	Learner1	Female	{0772de57-4355-403e-ae42-470139ddb5d4}	1,974609	13,655348
30	Polygon	38	classroom	wider in size	Learner1	Female	{4451cc54-2b5c-4c67-880f-18b41568a85}	268,326172	109,210925
31	Polygon	39	class	learning	Learner1	Female	{74b61ce3-be5c-4106-b314-3e0983518de0}	602,675781	158,59467
32	Polygon	40		long and tall	Learner1	Male	{3cc82706-357f-4401-8f1d-1abf9db990d8}	8,886719	89,845359
33	Polygon	41	library	bricks	Learner1	Female	{fb1dfa4f-d476-4b59-8d1d-e36a3fac7b43}	576,118164	90,47175
34	Polygon	42	water reserve	longish	Learner1	Female	{511d1364-14b6-4121-93e4-a3d62032dc4e}	2,873047	8,321024
35	Polygon	43	classes	tall	Learner1	Male	{bc15d14f-6ada-4e3b-9a20-a4ebc55c6b3c}	357,753906	162,607288
36	Polygon	44	water reserve	red	Learner1	Female	{39a154fa-05c5-4015-bf90-45385ec697b7}	3,441406	16,864959
37	Polygon	45	classroom	3d	Learner1	Male	{8fa08a39-2004-4b60-8250-87cbf266631b}	767,21875	209,078312
38	Polygon	46	classes	big	Learner1	Female	{3484d790-9c9a-45ad-8d41-b283b4f98e53}	220,129883	127,358143
39	Polygon	47	classroom	tall and Long	Learner1	Female	{247b7a31-a1f5-4f58-9fda-ccbbd278c332}	1079,069336	166,075319
40	Polygon	48	library	big	Learner1	Female	{855d01e0-76fc-4a13-ae3b-2e4e5d513cb3}	507,619141	89,454732
41	Polygon	49	library	3d	Learner 2	Male	{b57ac57b-b786-4ee9-a90c-27e4672f70c9}	332,257813	89,939895
42	Polygon	50	rusted tanks	was a food shelter(kitchen)			{ccfbb77-abbc-44be-95e5-ed8cf3d3295f}	16,545898	20,306891
43	Polygon	51	container		Learner1	Male	{b119e1fc-969d-49ae-ace0-266a31f7c82e}	39,280273	25,357883

(24 out of 110 Selected)

Polygons

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)

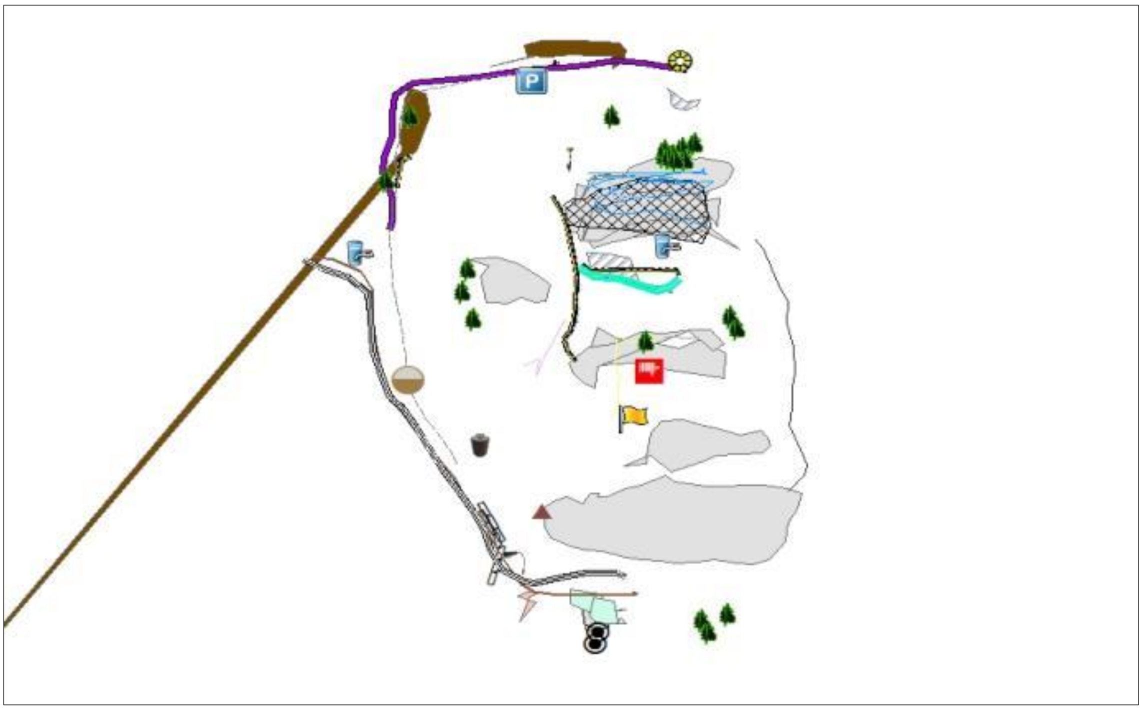


Figure 34: All features captured in School E

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).

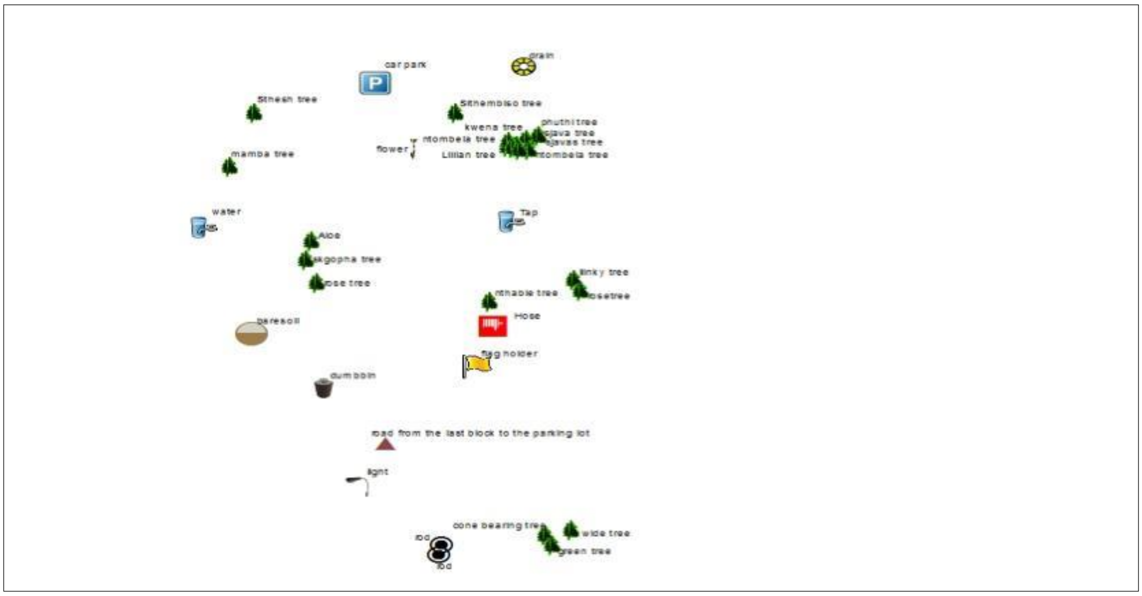
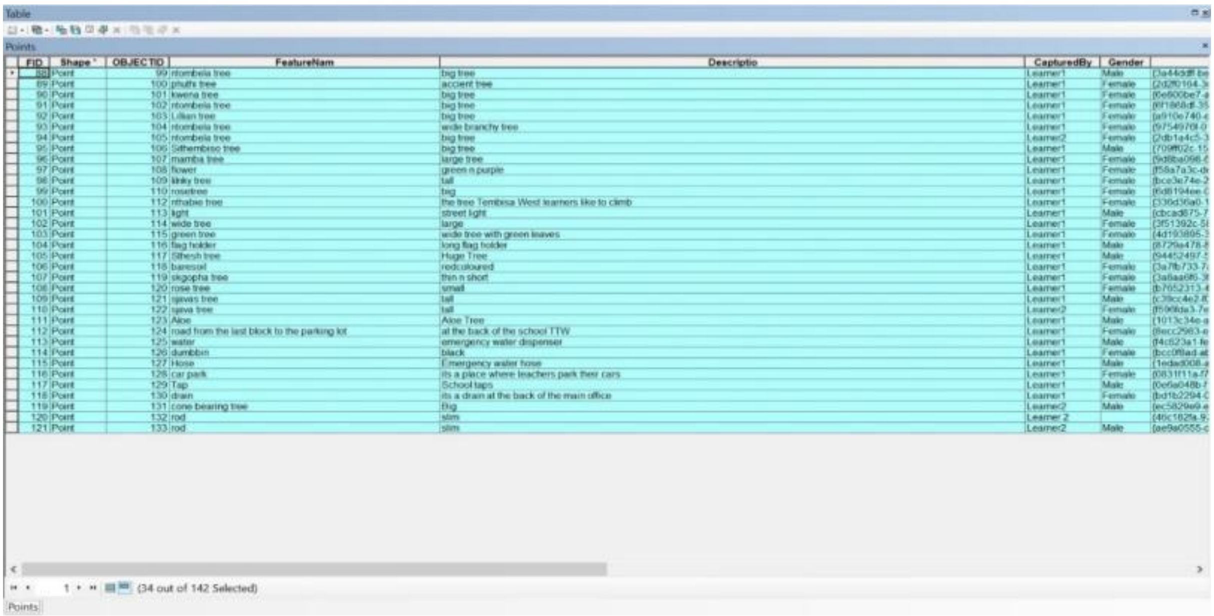


Figure 35: School E point features

Table 16: School E point attributes



Table

Points

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	
88	Point	99	ntombela tree	big tree	Learner1	Male	{3a44ddff-be
89	Point	100	phuthi tree	accent tree	Learner1	Female	{2d2f0104-3
90	Point	101	kwena tree	big tree	Learner1	Female	{6e600be7-a
91	Point	102	ntombela tree	big tree	Learner1	Female	{6f1868df-35
92	Point	103	Lilian tree	big tree	Learner1	Female	{a910e740-4
93	Point	104	ntombela tree	wide branchy tree	Learner1	Female	{97549708-0
94	Point	105	ntombela tree	big tree	Learner2	Female	{2db1a4c5-3
95	Point	106	Sithembiso tree	big tree	Learner1	Male	{709ff02c-15
96	Point	107	mamba tree	large tree	Learner1	Female	{9d8ba098-6
97	Point	108	flower	green n purple	Learner1	Female	{f58a7a3c-d
98	Point	109	linky tree	tall	Learner1	Female	{bce3e74e-2
99	Point	110	rosetree	big	Learner1	Female	{6d8194ee-0
100	Point	112	nthabie tree	the tree Tembisa West learners like to climb	Learner1	Female	{336d36a0-1
101	Point	113	light	street light	Learner1	Male	{cbcad875-7
102	Point	114	wide tree	large	Learner1	Female	{3f51392c-5
103	Point	115	green tree	wide tree with green leaves	Learner1	Female	{4d193895-3
104	Point	116	flag holder	long flag holder	Learner1	Male	{8729a478-8
105	Point	117	Sthesh tree	Huge Tree	Learner1	Male	{94452497-5
106	Point	118	baresoil	redcoloured	Learner1	Female	{3a7fb733-7
107	Point	119	skgopha tree	thin n short	Learner1	Female	{3a6aa6f6-3
108	Point	120	rose tree	small	Learner1	Female	{b7652313-4
109	Point	121	ujavas tree	tall	Learner1	Male	{c39cc4e2-8
110	Point	122	ujava tree	tall	Learner2	Female	{f59d6da3-7e
111	Point	123	Aloe	Aloe Tree	Learner1	Male	{1013c34e-a
112	Point	124	road from the last block to the parking lot	at the back of the school TTW	Learner1	Female	{8ecc2983-e
113	Point	125	water	emergency water dispenser	Learner1	Male	{f4c523a1-fe
114	Point	126	dumbbin	black	Learner1	Female	{bcc0f8ad-a
115	Point	127	Hose	Emergency water hose	Learner1	Male	{1eda4008-a
116	Point	128	car park	its a place where teachers park their cars	Learner1	Female	{0831f11a-f7
117	Point	129	Tap	School taps	Learner1	Male	{0e6a048b-f
118	Point	130	drain	its a drain at the back of the main office	Learner1	Female	{bd1b2294-0
119	Point	131	cone bearing tree	Big	Learner2	Male	{ec5829e9-e
120	Point	132	rod	slim	Learner 2		{46c1828a-9
121	Point	133	rod	slim	Learner2	Male	{ae9a0555-c

(34 out of 142 Selected)

Points

Line features

The line features that were captured included waterways, a pavement, the teachers' parking lot, a fence, roads, the assembly, a gutter, toilet blocks, and the *amazenke wemvula* (shelter that learners walk under) as indicated in Figure 36 and Table 17.

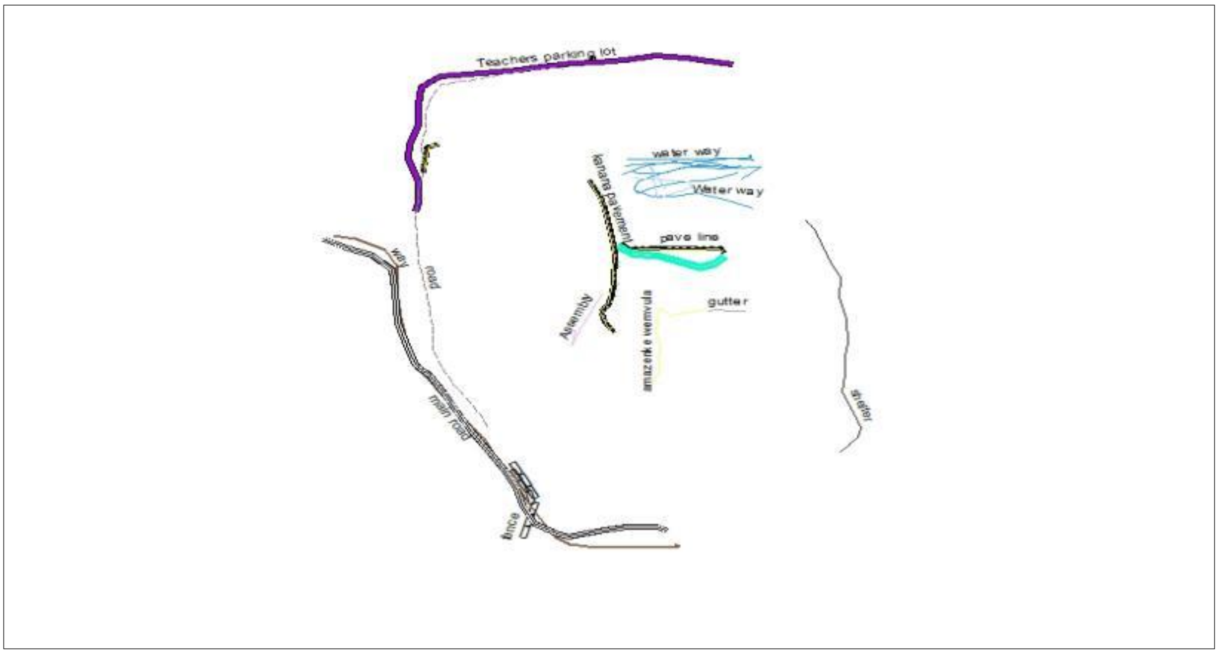


Figure 36: School E line features

Table 17: School E line attributes

Table

Lines

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID
67	Polyline	77	water wave	in front of c block	Learner1	Female	{aa8adb28-c487-4af2-ba97-313
68	Polyline	78	water run away	its infront of matric block of Tembisa West	Learner1	Female	{a2410f05-bda0-4ee5-8867-4c0
69	Polyline	80	water way	in block a	Learner1	Female	{6715286a-b844-4e95-baea-a2
70	Polyline	81	water way	in front of the office	Learner1	Male	{1218866f-591b-46dc-9370-778
71	Polyline	82	Water way	In front of block C	Learner1	Male	{c9d8fa41-e3f2-4ffc-a7ed-93e7a
72	Polyline	83	waterway	infront of block	Learner1	Female	{30214bfd-4ab6-45f1-81df-0d857
73	Polyline	84	rain pass	block a	Learner1	Female	{91f0b14d-b30e-45b1-a87f-89d2
74	Polyline	85	pave line	in front of toilets	Learner1	Female	{f0761e6b-7ca1-4048-a17a-2e4
75	Polyline	86	toilets blocks	infront of the girls toilets	Learner1	Female	{457b8050-47fe-4e89-8350-e2e
76	Polyline	87	kanana pavement	its a paving from matric block to grade 11 block	Learner1	Female	{5459613e-2be8-4ff3-9dd0-8d8
77	Polyline	88	pavement	entrance way	Learner1	Female	{33bbe175-12d3-4bcd-beb8-dbe
78	Polyline	89	Twss Pavement	roadside paving	Learner1	Female	{af41cd91-5b98-4de2-955c-384
79	Polyline	90	amazenke wemvula	a rain thing that learners walk under when its raining from the kitchen to the science lab	Learner1	Female	{634ca122-7530-4e44-b454-c6b
80	Polyline	91	Teachers parking lot	parking lot	Learner1	Male	{60109a7f-7438-491b-a998-651
81	Polyline	92	fence	block e	Learner1	Female	{bd394181-c234-4644-b0f1-77d
82	Polyline	93	gutter	fallen grey gatter	Learner1	Male	{4cce033d-c047-44b5-959b-632
83	Polyline	95	water way	in front of			{31123c01-d2a9-4ce1-a348-8bf
84	Polyline	96	Assembly	block ee	Learner1	Female	{d8f13e6a-8033-4b44-96e2-c7b
85	Polyline	97	road	from second last block to parking lot	Learner1	Female	{85acdc6c-927d-48d4-a585-61b
86	Polyline	98	shelter	walk way	Learner1	Male	{f01abe4-5eba-4bda-a3eb-53f
87	Polyline	99	way	thin	Learner1	Male	{f2a0a8b9-4d78-4293-b9fa-2da
88	Polyline	100	main road	big	Learner2	Male	{88e6b57e-b968-4f9b-b9d5-ef

(22 out of 112 Selected)

Lines

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.

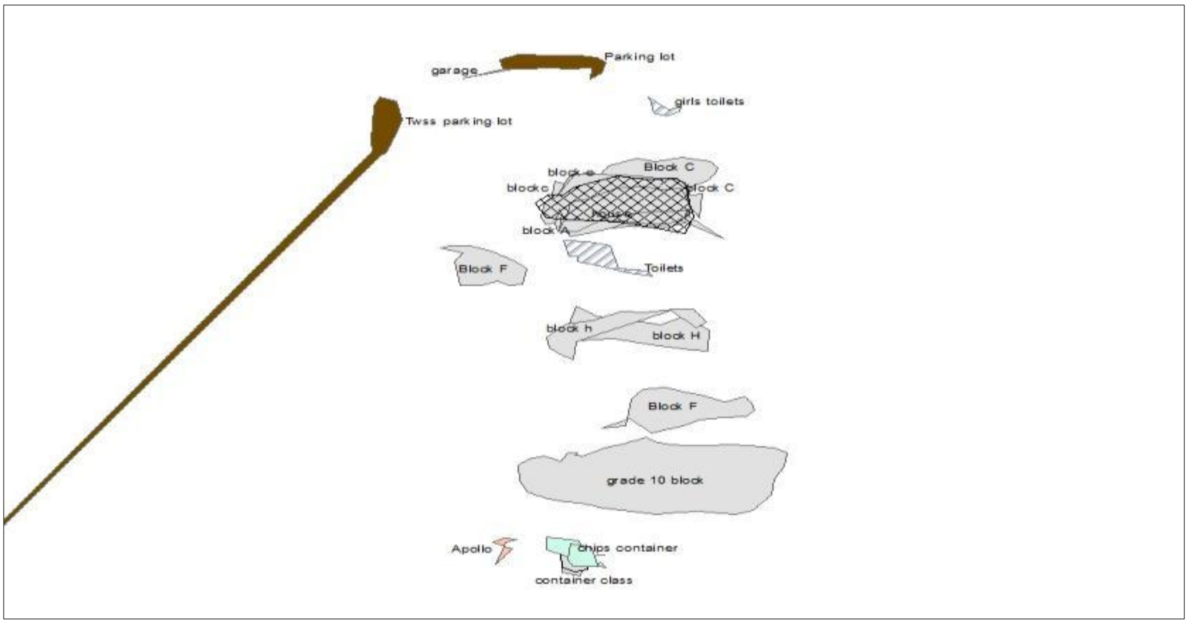


Figure 37: School E polygon features

Table 18: School E polygon attributes

Table

Polygons

FID	Shape *	OBJECTID	FeatureNam	Descriptio	CapturedBy	Gender	GlobalID	Shape__Are	Shape__Len
65	Polygon	73	block c	it have 3 classrooms	Learner1	Male	[illegible]	506,62793	92,737384
66	Polygon	74	block c	3	Learner1	Female	[illegible]	292,855469	199,937959
67	Polygon	75	blockc	3 classrooms	Learner2	Female	[illegible]	570,748047	101,67282
68	Polygon	76	block c	3 classrooms	Learner1	Female	[illegible]	593,599609	103,579794
69	Polygon	77	Block C	3 Classrooms	Learner1	Male	[illegible]	308,755859	107,578306
70	Polygon	78	block c	3 classrooms	Learner1	Female	[illegible]	526,811523	102,624724
71	Polygon	79	block C	three classrooms	Learner1	Female	[illegible]	651,673828	107,443378
72	Polygon	80	block A	3 classrooms	Learner1	Female	[illegible]	338,764648	108,34282
73	Polygon	81	Twiss parking lot	parking	Learner1	Female	[illegible]	585,848633	899,851147
74	Polygon	82	garage	paveway	Learner1	Female	[illegible]	3,237305	31,809221
75	Polygon	83	container class	1 room	Learner1	Female	[illegible]	59,262695	34,216158
76	Polygon	84	chips container	wide in size	Learner1	Female	[illegible]	47,291016	30,346848
77	Polygon	85	grade 10 block	its five classes plus a computer center	Learner1	Female	[illegible]	1623,718797	183,91939
78	Polygon	86	Block F	Storeroom	Learner1	Male	[illegible]	228,479492	70,225945
79	Polygon	87	Apollo	steal	Learner1	Female	[illegible]	17,736328	33,537414
80	Polygon	88	parking lot	long	Learner1	Female	[illegible]	148,841797	72,053145
81	Polygon	89	girls toilets	infront of block c	Learner1	Female	[illegible]	24,573242	27,304895
82	Polygon	90	block H	it have consumer study kitchen	Learner1	Male	[illegible]	363,669992	101,894295
83	Polygon	92	house	big	Learner1		[illegible]	644,12793	111,321979
84	Polygon	93	Toilets	Male and female toilets	Learner1	Male	[illegible]	114,631836	64,590781
85	Polygon	94	block h	roof	Learner1	Female	[illegible]	226,47168	112,135493
86	Polygon	95	Block F	4 Classrooms	Learner1	Male	[illegible]	381,256836	105,899295
87	Polygon	96	zozo	big	Learner1	Male	[illegible]	61,556641	41,292486
88	Polygon	97	zozo	big	Learner2	Male	[illegible]	59,374023	36,282915

1 (24 out of 110 Selected)

Polygons

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.

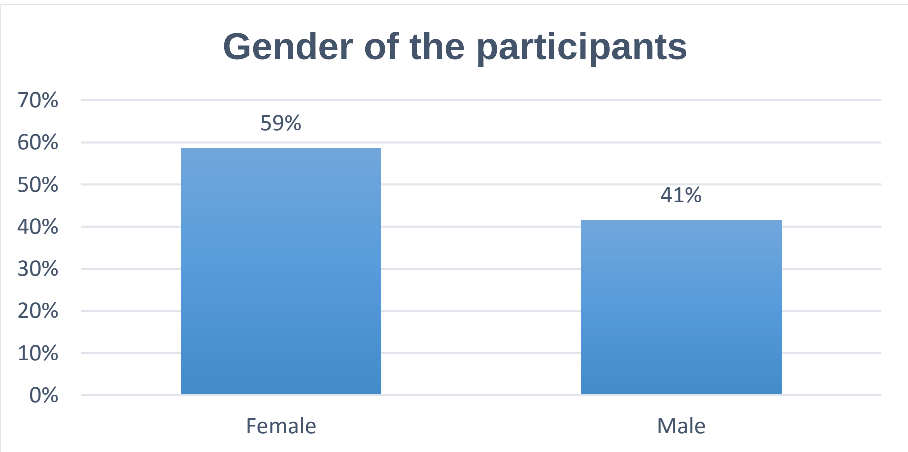


Figure 38: Gender of the participants

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.

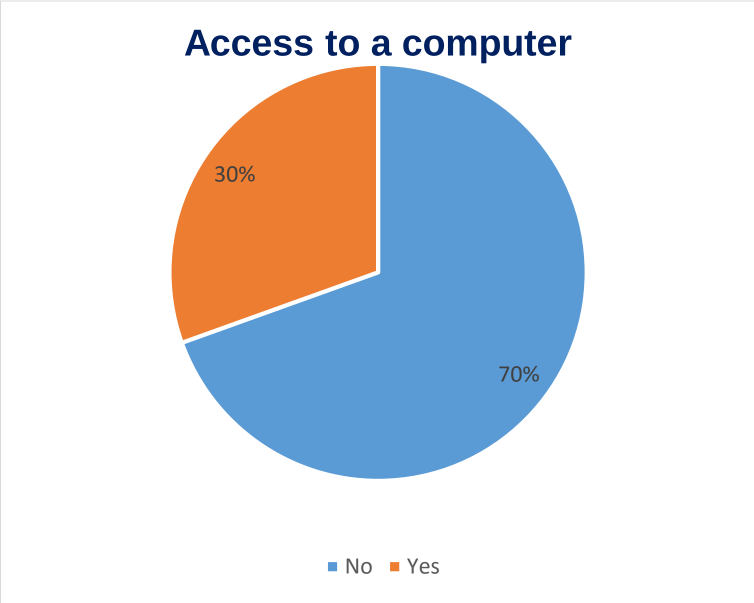


Figure 39: Access to a computer

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.

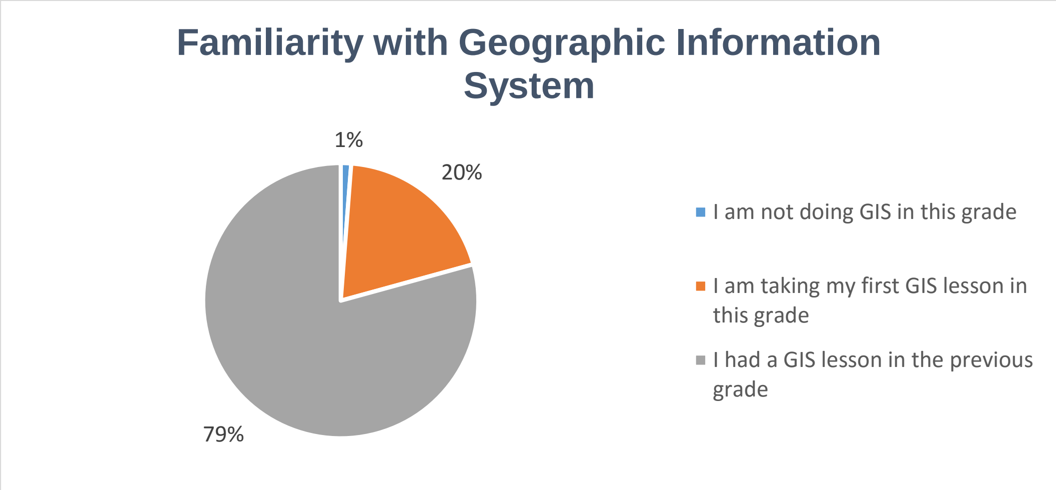


Figure 40: Familiarity with GIS

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.

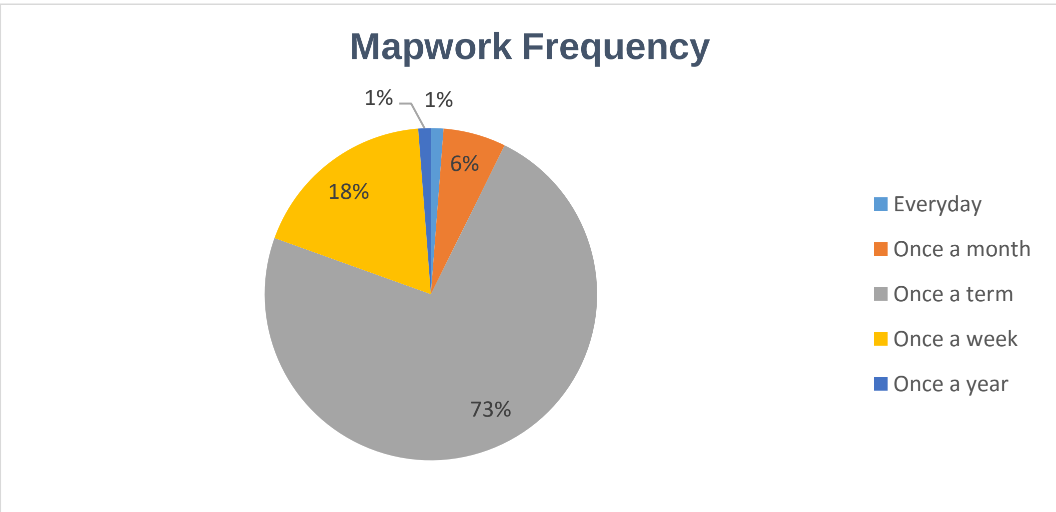


Figure 41: Mapwork in the classroom

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.

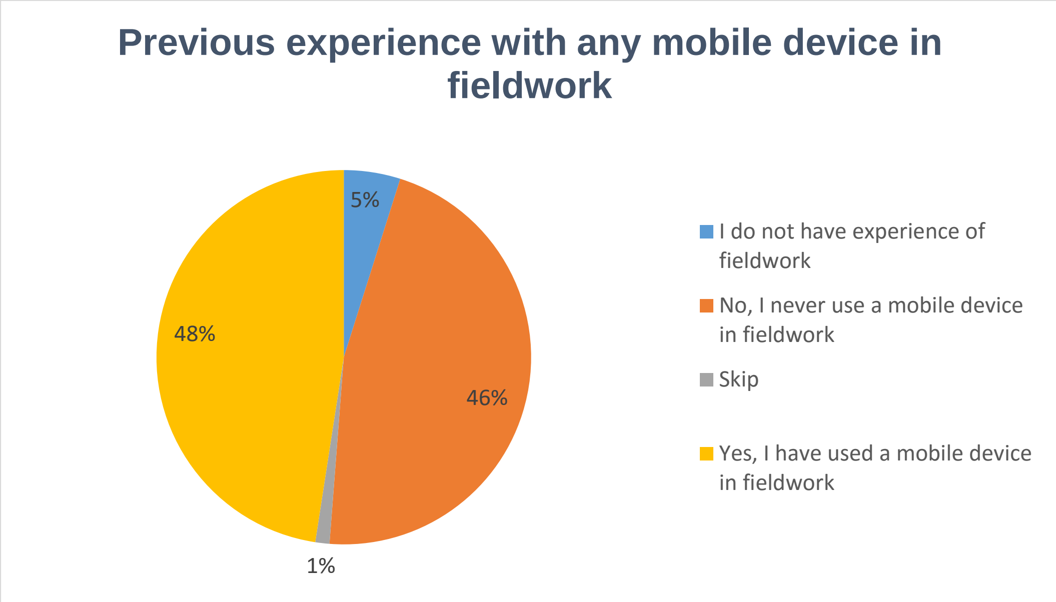


Figure 42: Previous experience with any mobile device in fieldwork

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 leaners

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.

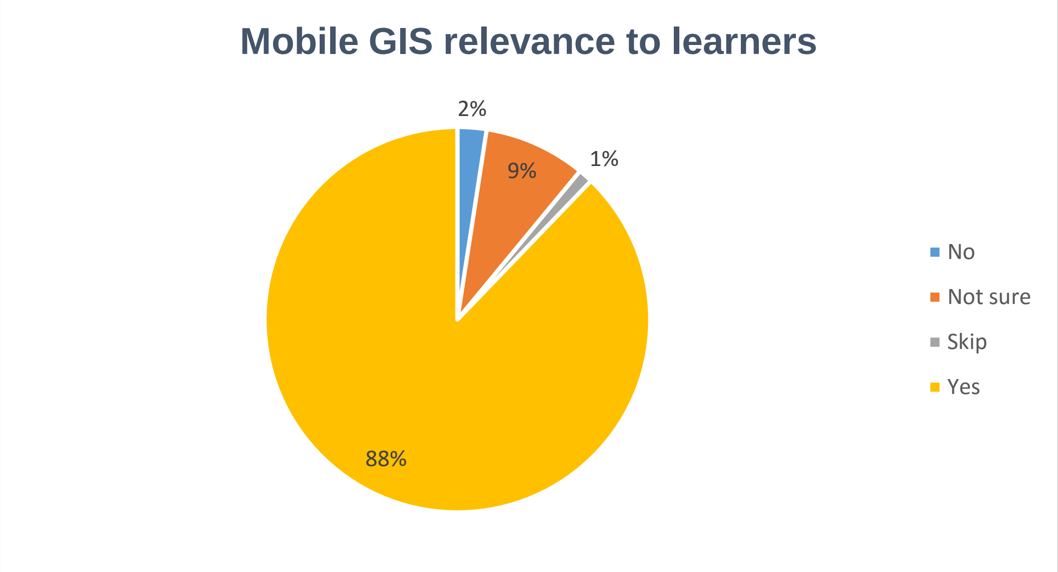


Figure 43: Mobile GIS relevance to learners

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

Q8 – What problems did you experience when you were using mobile GIS	No. of participants	% of participants
Map too small, signal loss.	1	1%

Q8 – What problems did you experience when you were using mobile GIS	No. of participants	% of participants
Screen too small, map too small, I was able to capture geographic features but not their attributes.		1%
Keyboard not user-friendly.	1	1%
Other: It was my first time doing it with a phone but it was fine honestly.	1	1%
Map too small.	7	9%
Screen too small.	9	11%
Signal loss.	11	13%
I was able to capture geographic features but not their attributes.	20	24%
None.	31	38%

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.

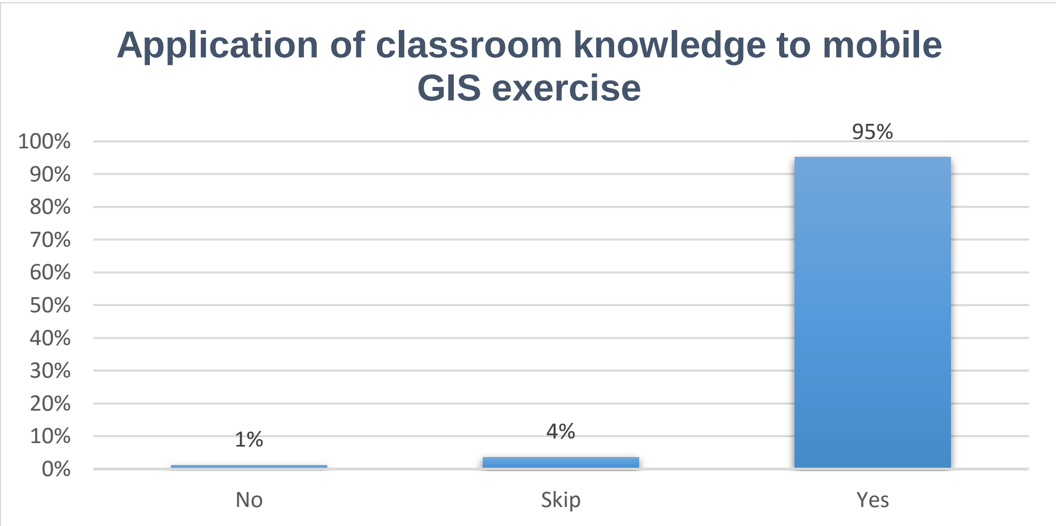


Figure 44: Application of classroom knowledge to mobile GIS exercise

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.

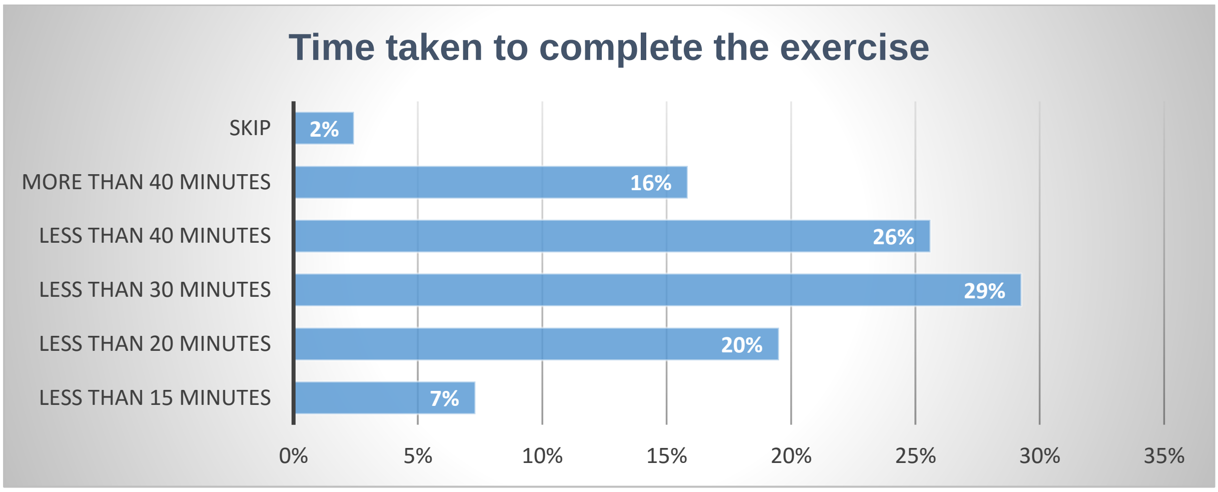


Figure 45: Time taken to complete the exercise

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.

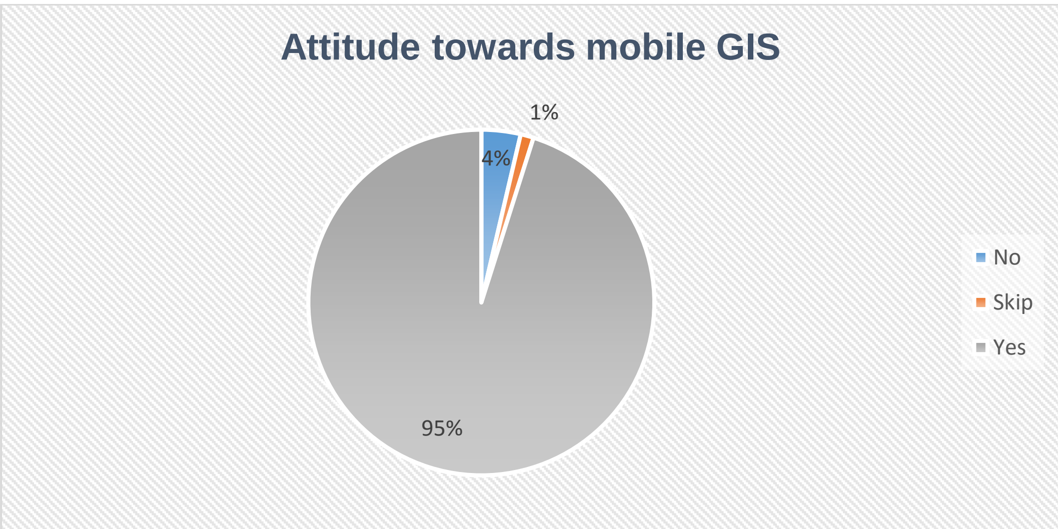


Figure 46: Attitude towards mobile GIS

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.

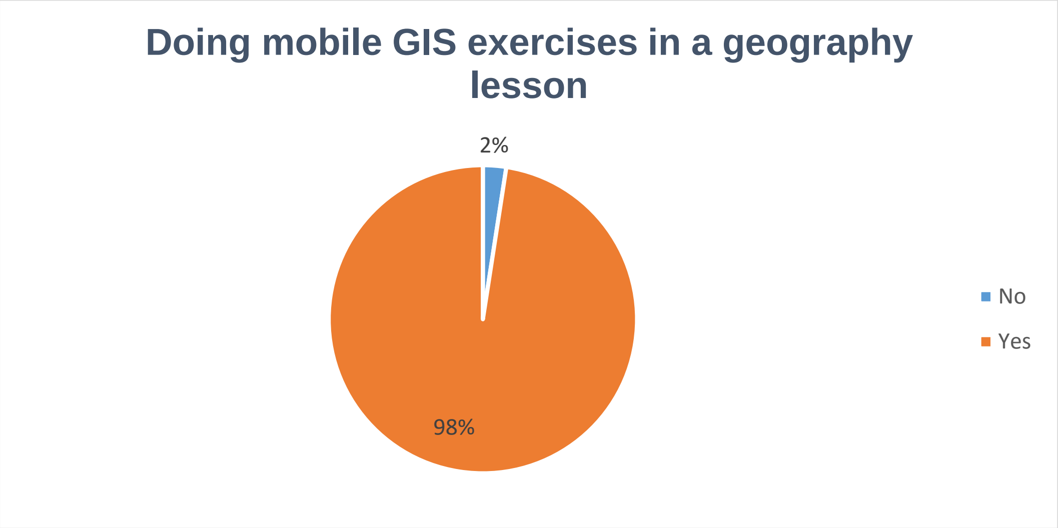


Figure 47: Mobile GIS exercises in a geography lesson

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.

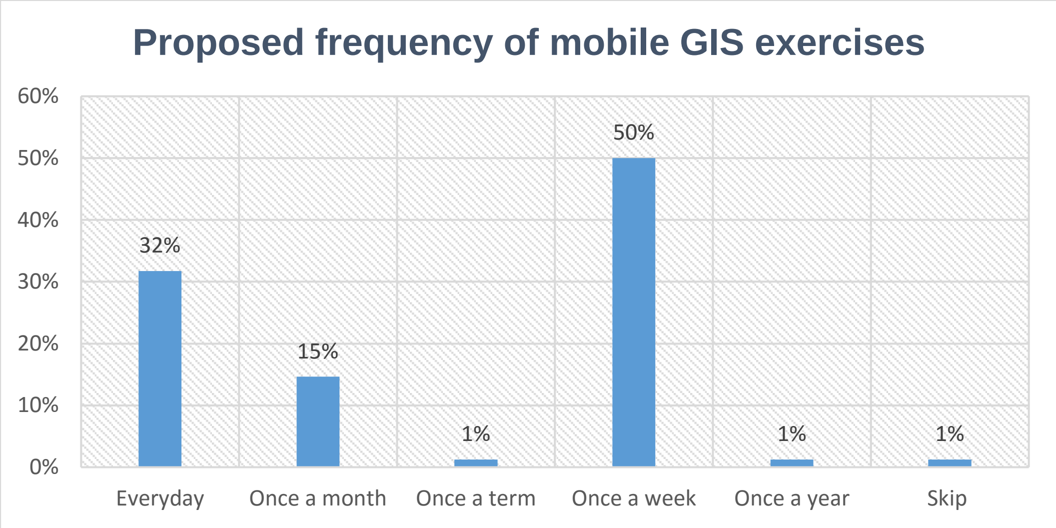


Figure 48: Proposed frequency of mobile GIS exercises

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

REFERENCES

AKINYEMI, F. O. 2015. An assessment of GIS use for teaching in Rwandan secondary schools. *The Geography Teacher,* 12, 27-40.

AL-EMRAN, M. & SHAALAN, K. 2015. Learners and educators attitudes towards mobile learning in higher education: State of the art. In: *2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, Kochi, India, 10-13 Aug. 2015. 907-913.

ALLEN, T. R. 2008. Digital terrain visualization and virtual globes for teaching geomorphology. *Journal of Geography,* 106, 253-266.

ARMSTRONG, M. P. & BENNETT, D. A. 2005. A manifesto on mobile computing in geographic education. *The Professional Geographer,* 57, 506-515.

ARTVINLI, E. 2010. The contribution of geographic information systems (GIS) to geography education and secondary school students' attitudes related to GIS. *Educational Sciences: Theory and Practice,* 10, 1277-1292

AUDET, R. H. & PARIS, J. 1997. GIS implementation model for schools: Assessing the critical concerns. *Journal of Geography,* 96, 293-300.

BABBIE, E. 2013. *The Practice of Social Research,* Belmont, CA: Wadsworth Cengage Learning.

BEDNARZ, S. 2004. Geographic information systems: A tool to support geography and environmental education? *GeoJournal,* 60, 191-199.

BREETZKE, G., EKSTEEN, S. & PRETORIUS, E. 2011. Paper-based GIS: A practical answer to the implementation of GIS education into resource-poor schools in South Africa. *Journal of Geography,* 110, 148-157.

BRITZ, H. W. & WEBB, P. 2016. The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners. *South African Geographical Journal,* 98, 182-193.

BRODA, H. W. & BAXTER, R. E. 2003. Using GIS and GPS technology as an instructional tool. *The Social Studies,* 94, 158-160.

CARLSON, T. 2007. A field-based learning experience for introductory level GIS students. *Journal of Geography,* 106, 193-198.

ÇEPNI, O. 2013. The use of geographic information systems (GIS) in geography teaching. *World Applied Sciences Journal,* 25, 1684-1689.

CHEUNG, W. S. & HEW, K. F. 2009. A review of research methodologies used in studies on mobile handheld devices in K-12 and higher education settings. *Australasian Journal of Educational Technology,* 25, 153-183.

CHUANG, Y.-T. 2015. *Utilizing mobile technology in GIS education: A case study of using iPad and iBooks in fieldwork and location based exercises*. Master of Science in Geography, San Diego State University, San Diego, CA.

CILLIERS, D. P., DE KLERK, T. C. & SANDHAM, L. A. 2013. Reflecting on GIS-related research in South Africa: 1980–2012. *South African Geographical Journal,* 95, 70-90.

CRABB, K. D. 2001. *Case study of geographic information system integration in a high school world geography classroom*. PhD thesis, University of Georgia, Athens, GA.

CYVIN, J. 2013. Challenges related to interdisciplinary use of digital mapping technology in primary and lower secondary schools. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography,* 67, 162-171.

DASCOMBE, B. 2006. Making geographic information systems (GIS) sustainable in schools. *International Research in Geographical and Environmental Education,* 15, 265-267.

DEMIRCI, A. 2008. Evaluating the implementation and effectiveness of GIS-based application in secondary school geography lessons. *American Journal of Applied Sciences* [Online]. Available: http://thescipub.com/pdf/10.3844/ajassp.2008.169.178 [Accessed 13 May 2018].

DEMIRCI, A. 2011. Using geographic information systems (GIS) at schools without a computer laboratory. *Journal of Geography,* 110, 49-59.

DEMIRCI, A., KARABURUN, A. & KILAR, H. 2013. Using Google Earth as an educational tool in secondary school geography lessons. *International Research in Geographical and Environmental Education,* 22, 277-290.

DEPARTMENT OF BASIC EDUCATION, REPUBLIC OF SOUTH AFRICA. 2011. *National Curriculum Statement (NCS): Curriculum and Assessment Policy Statement Geography*. Pretoria, South Africa: Government Printing Works.

DICTIONARY.COM n.d. *Mobile device*. Available: http://www.dictionary.com/browse/mobile-device [Accessed 13 May 2018].

DOBSON, J. E. 2008. *Bring back geography! Essays on geography and GIS.* Available: https://www.esri.com/library/bestpractices/essays-on-geography-gis.pdf [Accessed 10 December 2018].

DONERT, K. 2007. Geoinformation in European education: A revolution waiting to happen. *In:* DONERT, K., CHARZYŃSKI, P. & PODGÓRSKI, Z. (eds.), *Teaching Geography In and About Europe.* Toruń, Poland: Herodot Network.

DRUMMOND, J., BILLEN, R., JOAO, E. & FORREST, D. 2006. *Dynamic and Mobile GIS: Investigating Changes in Space and Time*. Boca Raton, FL: CRC Press.

ELEICHE, M. A. 2011. *Network analysis methods for mobile GIS.* PhD, University of West Hungary, Sopron, Hungary.

ELWOOD, S. & COPE, M. 2009. *Qualitative GIS: A Mixed Methods Approach*. London, UK: SAGE.

ESRI. n.d. *GIS best practices: Mobile GIS*. Available: http://www.esri.com/library/bestpractices/mobile-gis.pdf [Accessed 10 May 2018].

FAVIER, T. & VAN DER SCHEE, J. 2009. Learning geography by combining fieldwork with GIS. *International Research in Geographical and Environmental Education,* 18, 261-274.

FLEISCHMANN, E. M.-L. & VAN DER WESTHUIZEN, C. P. 2017. The Interactive-GIS-Tutor (IGIST): An option for GIS teaching in resource-poor South African schools. *South African Geographical Journal,* 99, 68-85.

FLEMING, B. GIS interventions that work at secondary level education (high school) in South Africa: Some recent success stories. *Geomatics Indaba 2015*, Emperors Palace, Kempton Park.

FOUCHÉ, C. B. & BARTLEY, A. 2012. Quantitative data analysis and interpretation. *In:* DE VOS, A. S., STRYDOM, H., FOUCHÉ, C. B. & DELPORT, C. S. L. (eds.), *Research at Grassroots: for the Social Sciences and Human Service Professions.* 4th ed. Pretoria: Van Schaik.

FRANCE, D. & HAIGH, M. 2018. Fieldwork@40: Fieldwork in geography higher education. *Journal of Geography in Higher Education,* 42, 498-514.

HEYWOOD, I., CORNELIUS, S. & CARVER, S. 2006. *An Introduction to Geographical Information Systems* Essex. London, UK: Pearson.

HOUTSONEN, L. 2006. GIS in the school curriculum: Pedagogical viewpoints. *In:* JOHANSSON, T. (ed.), *Geographical Information Systems Applications for Schools: GISAS.* Helsinki, Finland: GISAS.

HSU, T.-Y. & CHEN, C.-M. 2010. A mobile learning module for high school fieldwork. *Journal of Geography,* 109, 141-149.

IDA, Y. & YUDA, M. 2012. Japan: GIS-Enabled field research and a cellular phone GIS application in secondary schools. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.), *International Perspectives on Teaching and Learning with GIS in Secondary Schools.* New York, NY: Springer.

INCEKARA, S. 2012. Do geographic information systems (GIS) move high school geography education forward in Turkey? A teacher's perspective. DOI: 10.5772/32851

INNES, L. & VAN DER WILLIGEN, C. 2008. Preparing future spatial decision makers: Using self instruction and GIS to improve map skills in the classroom. In: *GDEST 2008 Conference,* Cape Town, 17-19 March.

INNES, L. M. 2012. South African school geography: Underpinning the foundation of geospatial competence. *South African Journal of Geomatics,* 1, 92-108.

INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT. 2009. *Participatory Geographical Information System.* Available: www.iapad.org/wp-content/.../07/EM-Profiles-No-7-Participatory-GIS-6-Oct-09.pdf [Accessed 10 May 2018].

JOHANSSON, T. 2006. GISAS project in a nutshell. *In:* JOHANSSON, T. (ed.), *Geographical Information Systems Applications for Schools: GISAS.* Helsinki, Finland: GISAS.

KANKAANRINTA, I.K. 2006. Teaching and learning geographical information systems effectively: Reflections in teachers' pedagogical diaries. *In:* JOHANSSON, T. (ed.), *Geographical Information Systems Applications for Schools: GISAS.* Helsinki, Finland: GISAS.

KENT, M., GILBERTSON, D. D. & HUNT, C. O. 1997. Fieldwork in geography teaching: A critical review of the literature and approaches. *Journal of Geography in Higher Education,* 21, 313-332.

KERSKI, J. J. 2003. The implementation and effectiveness of geographic information systems technology and methods in secondary education. *Journal of Geography,* 102, 128-137.

KERSKI, J. J. 2008. The role of GIS in Digital Earth education. *International Journal of Digital Earth,* 1, 326-346.

KERSKI, J. J. 2011. *Sleepwalking into the future: The case for spatial analysis throughout education*. Available: http://gispoint.de/fileadmin/user_upload/paper_gis_open/537510017.pdf [Accessed 30 April 2018].

KERSKI, J. J. 2017. Water quality. *The Geography Teacher,* 14, 36-41.

KERSKI, J. J., DEMIRCI, A. & MILSON, A. J. 2013. The global landscape of GIS in secondary education. *Journal of Geography,* 112, 232-247.

KINGSTON, D. G., EASTWOOD, W. J., JONES, P. I., JOHNSON, R., MARSHALL, S. & HANNAH, D. M. 2012. Experiences of using mobile technologies and virtual field tours in physical geography: Implications for hydrology education. *Hydrology and Earth System Sciences,* 16, 1281–1286.

KOLVOORD, R., KERANEN, K. & RITTENHOUSE, P. 2017. Applications of location-based services and mobile technologies in K-12 classrooms. *International Journal of Geo-Information,* 6, 1-9.

KOMLENOVICS, D., MALINIC, D., & MANIC, E. 2013. The Geographic Information System (GIS) in secondary education in Serbia*. Perspectives in Education,* 31, 96-104.

KOUTSOPOULOS, K. C. 2010. Teaching geography: Instructing with GIS and about GIS. *In:* DONERT, K. (ed.), *Using GeoInformation in European Geography Education.* Rome: International Geographic Union – Home of Geography.

LAMBRIONOS, N. & ASIKLARI, F. 2014. The introduction of GIS and GPS through local history teaching in primary school. *European Journal of Geography,* 5, 32-47.

LAWRENCE, M. & SCHLEICHER, Y. 2010. Mobile learning and GPS: From geocaching to participatory GIS. *In:* DONERT, K. (ed.), *Using GeoInformation in European Geography education.* Rome: International Geographic Union – Home of Geography.

LEUNG, J. T.-Y. & SHEK, D. T.-L. 2018. Quantitative research methods. *In:* FREY, B. B. (ed.), *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation.* Thousand Oaks, CA: SAGE.

LI, L., LI, C. & LING, Z. 2002. Investigation on the concept of Mobile GIS. *Symposium on Geospatial Theory, Processing and Applications*, Ottawa, 9–12 July.

LI, Q. 2007. Opportunities in mobile GIS. *In:* BILLEN, R., JOÃO, E. & FORREST, D. (eds.), *Dynamic and Mobile GIS: Investigating Changes in Space and Time.* Boca Raton, FL: CRC Press.

LI, Y. & BRIMICOMBE, A. J. 2013. Mobile geographic information systems. *In: Geographic Information Systems: Concepts, Methodologies, Tools, and Applications.* Hershey, PA: IGI Global.

LIU, S. & ZHU, X. 2008. Designing a structured and interactive learning environment based on GIS for secondary geography education. *Journal of Geography,* 107, 12-19.

MAANTAY, J. & ZIEGLER, J. 2006. *GIS for the urban environment.* Redlands, CA: ESRI Press.

MACDEVETTE, D. R., FINCHAM, R. J. & FORSYTH, G. G. 2005. The rebuilding of a country: The role of GIS in South Africa. *In:* LONGLEY, P. A., GOODCHILD, M. F., MAGUIRE, D. J. & RHIND, D. W. (eds.), *Geographical Information Systems: Principles, Techniques, Management and Applications.* 2nd ed. San Francisco, CA: Wiley.

MAGUIRE, D. J. 1991. An overview and definition of GIS. *Geographical Information Systems: Principles and Applications,* 1, 9-20.

MAHBUBUR, R. M., JOHN, A. S. & SHARMIN, Y. 2013. Coupling GPS and GIS. *In: Geographic Information Systems: Concepts, Methodologies, Tools, and Applications.* Hershey, PA: IGI Global.

MARTIN, F. & ERTZBERGER, J. 2013. Here and now mobile learning: An experimental study on the use of mobile technology. *Computers & Education,* 68, 76-85.

MERRIAM-WEBSTER. n.d. *Student* [Online]. Available: https://www.merriam-webster.com/dictionary/student [Accessed 26 March 2019].

MILSON, A. J. & KERSKI, J. J. 2012. United States of America: Rugged terrain and fertile ground for GIS in secondary schools. *In:* MILSON A.J. & J.J., K. (eds.), *International Perspectives on Teaching and Learning with GIS in Secondary Schools.* Dordrecht: Springer.

MITCHELL, J. T., ROY, G., FRITCH, S. & WOOD, B. 2018. GIS professional development for teachers: Lessons learned from high-needs schools. *Cartography and Geographic Information Science*, 1-13.

MUIJS, D. 2010. *Doing Quantitative Research in Education with SPSS*. 2nd ed. London, UK: SAGE.

MURAYAMA, Y. 2000. Geography with GIS. *GeoJournal,* 52, 165-171.

NEUMANN, K. & KUTIS, M. 2006. Mobile GIS in geologic mapping exercises. *Journal of Geoscience Education,* 54, 153-157.

NISHISHIBA, M., JONES, M. & KRANER, M. 2014. *Research Methods and Statistics for Public and Nonprofit Administrators: A Practical Guide*. London, UK: SAGE.

PÁNEK, J. & GLASS, M. 2018. Gaining a mobile sense of place with collector for ArcGIS. *Journal of Geography in Higher Education,* 42, 603-616.

PEACOCK, J., MEWIS, R. & ROONEY, D. 2018. The use of campus based field teaching to provide an authentic experience to all students. *Journal of Geography in Higher Education,* 42, 531-539.

PEIRCE, S. 2016. Making learning mobile: Using mobile technologies to bring GIS into the geography classroom. *Teaching Innovation Projects,* 6, 1-8.

PICKLES, J. 1995. Representations in an electronic age: Geography, GIS, and democracy. *Ground Truth: The Social Implications of Geographic Information Systems.* New York, NY: The Guilford Press.

POSITION IT. October 2015. *Northern Cape teachers receive GIS training*. Available: https://www.ee.co.za/article/northern-cape-teachers-receive-gis-training.html [Accessed 21 November 2018].

REPUBLIC OF SOUTH AFRICA. 1996*. South African Schools Act 84 of 1996*. Available:https://www.gdeadmissions.gov.za/Content/Files/SchoolsAct.pdf [Accessed 26 March 2019].

SOUTH AFRICAN COUNCIL FOR EDUCATORS (SACE). n.d. *The code of professional ethics (as amended)*.Available: https://www.sace.org.za/pages/the-code-of-professional-ethics [Accessed 26 March 2019]

STEINBERG, S. J. & STEINBERG, S. L. 2006. *Geographic Information Systems for the Social Sciences: Investigating Space and Place*. Thousand Oaks, CA: SAGE.

STEWART, M., CLARK, J. J., DONALD, J. W. & VAN CAMP, K. 2011. The educational potential of mobile computing in the field. *EDUCAUSE Review*.

STONIER, F. 2015. Introducing future educators to GIS data collection. *International Journal of Digital Society (IJDS),* 6, 1021-1026.

STRYDOM, H. 2012. Sampling in the quantitative paradigm. *In:* DE VOS, A. S., STRYDOM, H., FOUCHÉ, C. B. & DELPORT, C. S. L. (eds.), *Research at Grassroots: For the Social Sciences and Human Service Professions.* Pretoria: Van Schaik Publishers.

SUMARI, N. S., SHAO, Z. & KIRA, E. 2017. Challenges and opportunities for the advancement of GIS education in Tanzania. *Journal of Education and Practice* 8, 67-75.

TECHNOPEDIA. n.d. *Mobile application (mobile app)* [Online]. Available: https://www.techopedia.com/definition/2953/mobile-application-mobile-app [Accessed 13 May 2018].

TSOU, M.-H. 2004. Integrated mobile GIS and wireless Internet map servers for environmental monitoring and management. *Cartography and Geographic Information Science,* 31, 153-165.

TSOU, M.-H. & KIM, I.-H.2010. Increasing spatial awareness by integrating Internet geographic information services (GIServices) with real time wireless mobile GIS applications. In: Information Resources Management Association (ed.), *Wireless Technologies: Concepts, Methodologies, Tools and Applications*. Hershey, PA: IGI Global.

TSOU, M.-H. & YANOW, K. 2010. Enhancing general education with geographic information science and spatial literacy. *URISA Journal* 22, 45-54.

UNEP/GRID-WARSAW CENTRE (ed.) 2011. GIS at School: Guidebook for Biology, Geography, and Science Teachers. Warsaw: UNEP/GRID.

WENG, T.-S. & LING, H. C. 2007. The study of e-learning for geographic information curriculum in higher education. In: *6th WSEAS International Conference on Applied Computer Science*, Hangzhou, China, 15–17 April. 616-621.

WORBOYS, M. & DUCKHAM, M. 2004. *GIS: A Computing Perspective,* Boca Raton, CRC Press.

ZOLDOSOVA, K. & PROKOP, P. 2006. Education in the field influences children's ideas and interest toward science. *Journal of Science Education and Technology,* 15, 304-313.

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.

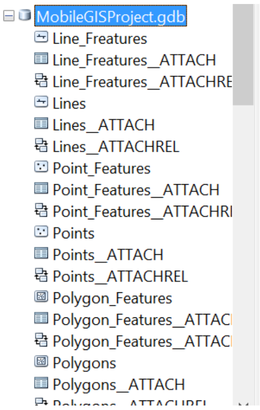


Figure 49: MobileGISProject

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.

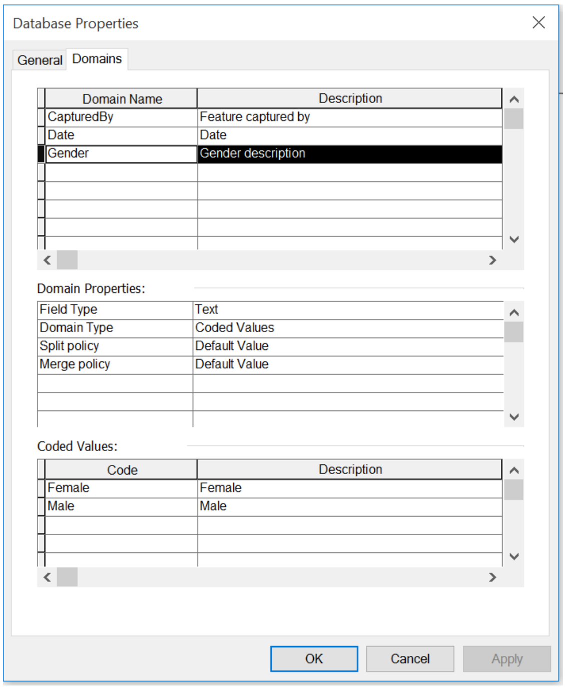


Figure 50: Creating domains

Creating feature classes

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

Polygon features

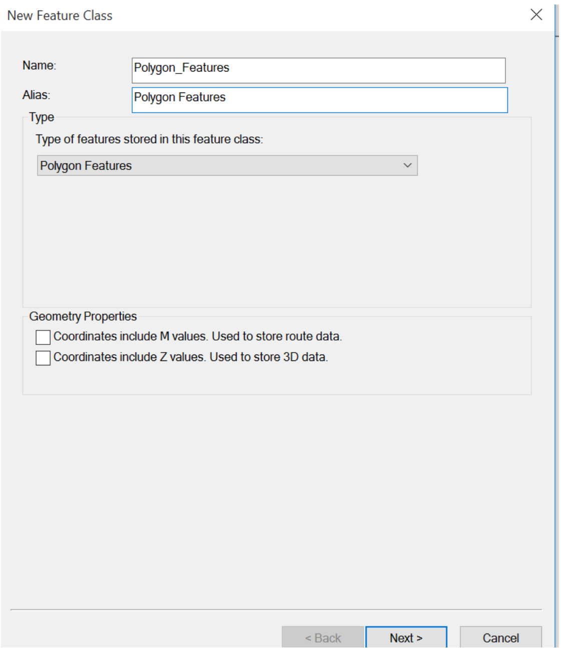


Figure 51: Polygon feature class

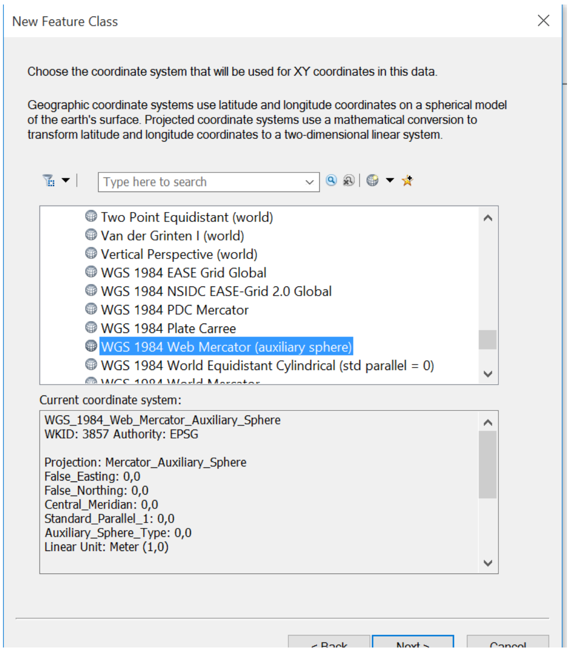


Figure 52: Polygon feature class coordinate system

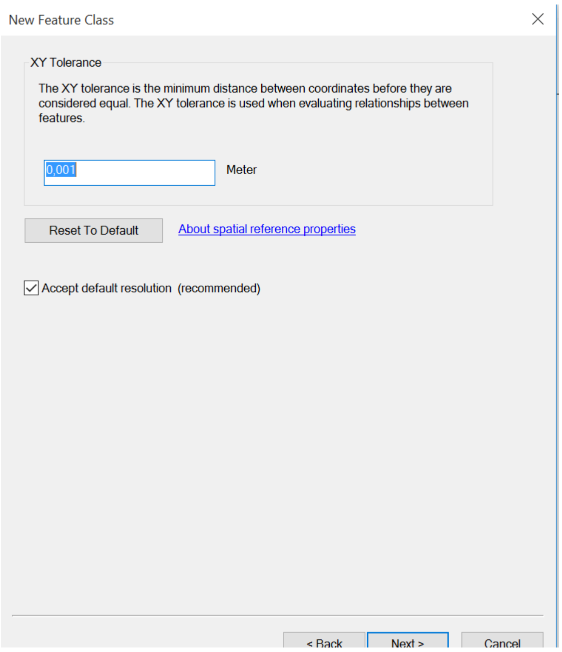


Figure 53: Polygon feature coordinate system XY tolerance

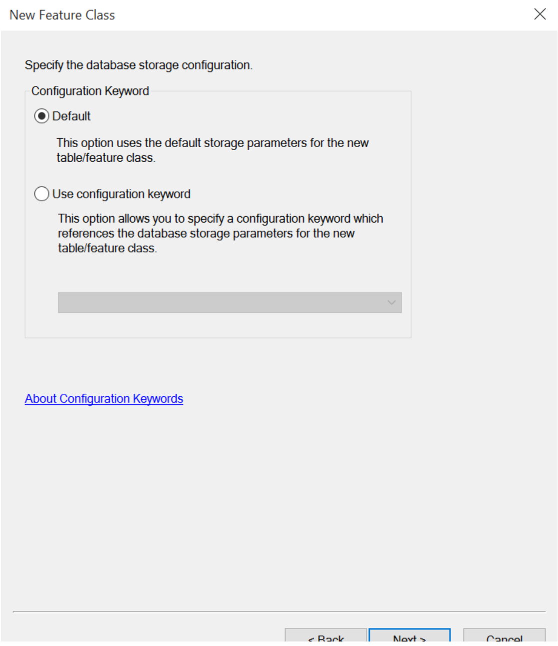


Figure 54: Polygon database storage configuration

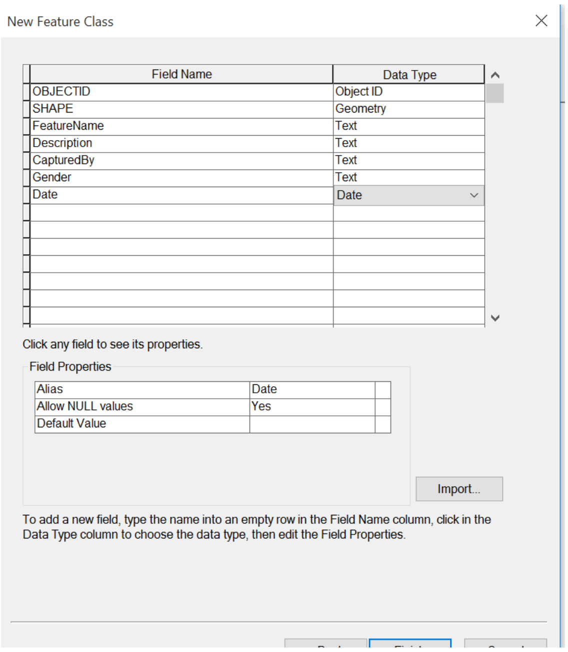


Figure 55: Polygon feature class fields

Line features

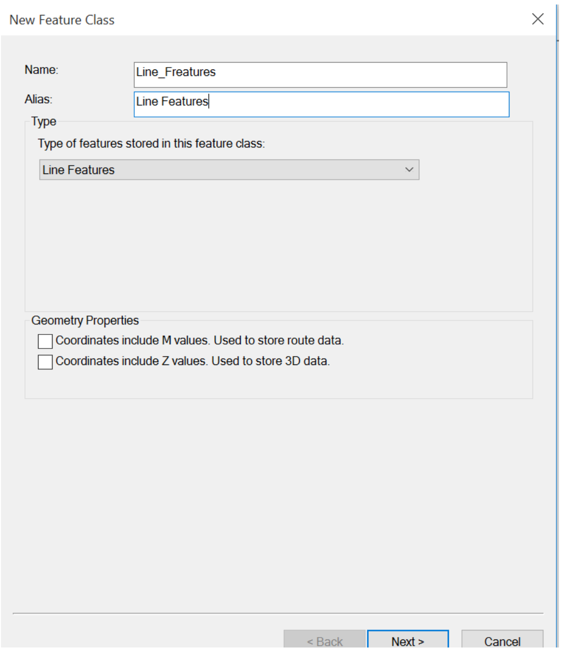


Figure 56: Line feature class

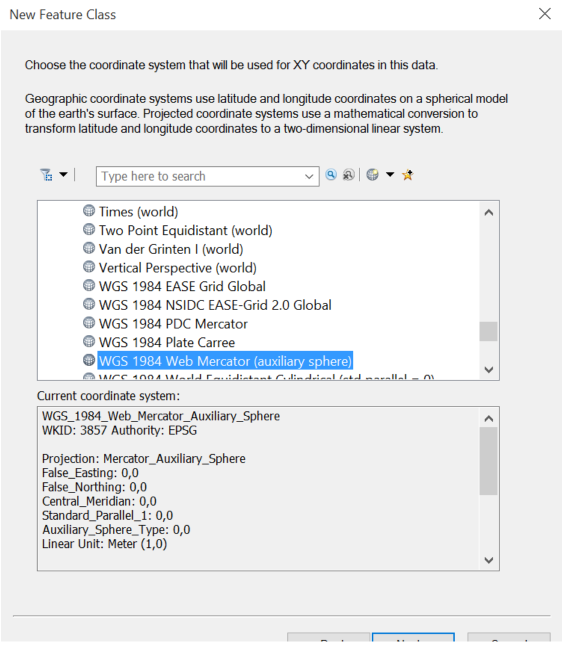


Figure 57: Line feature class coordinate system

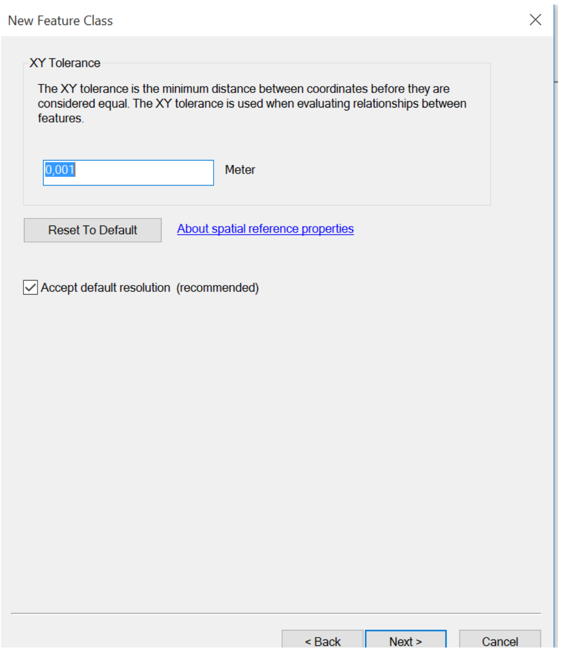


Figure 58: Line feature coordinate system XY tolerance

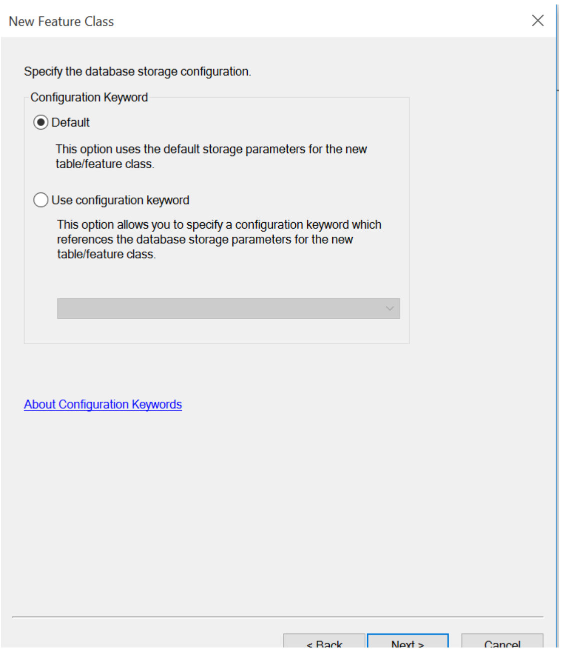


Figure 59: Line database storage configuration

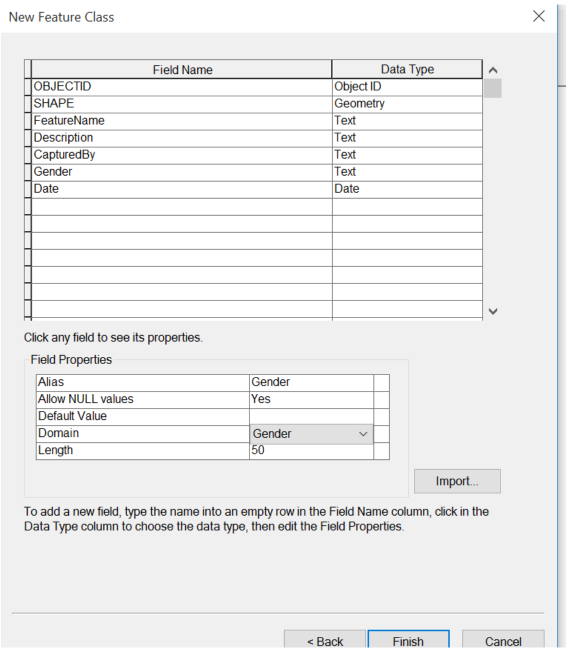


Figure 60: Line feature class fields

Point features

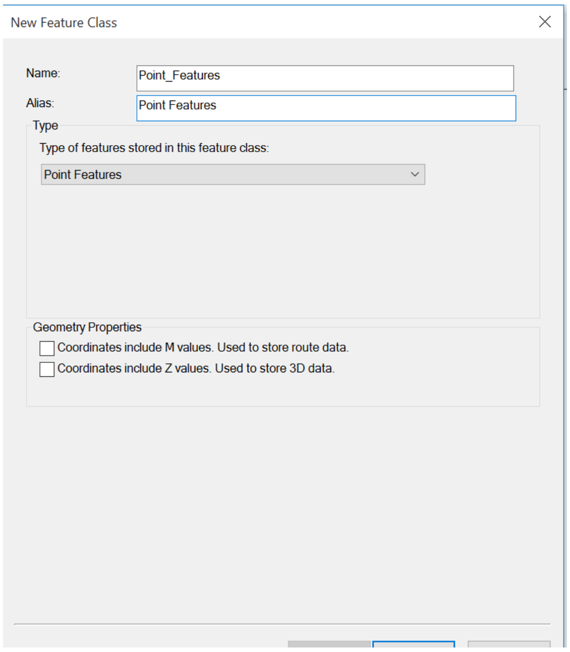


Figure 61: Point feature class field

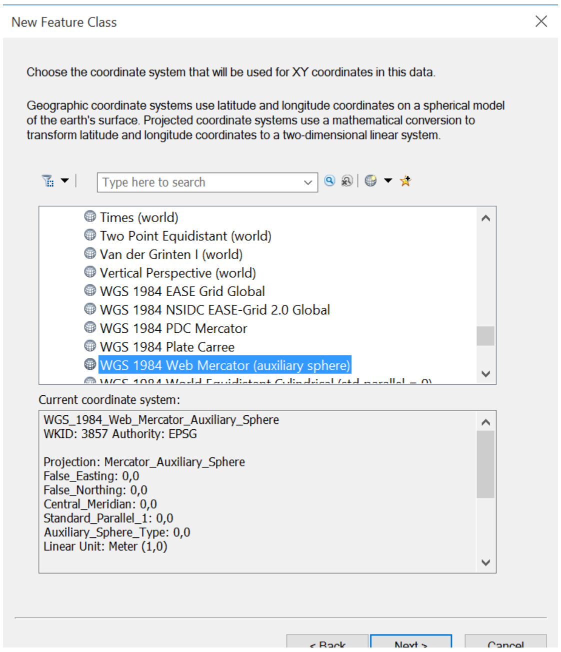


Figure 62: Point feature coordinate system

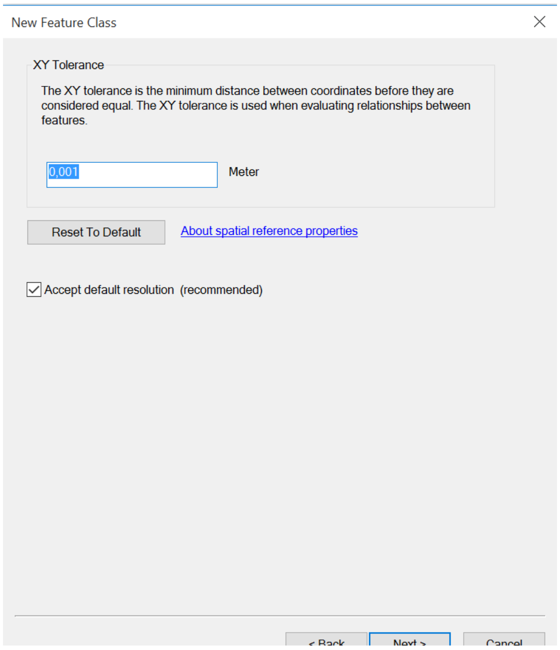


Figure 63: Line feature coordinate system XY tolerance

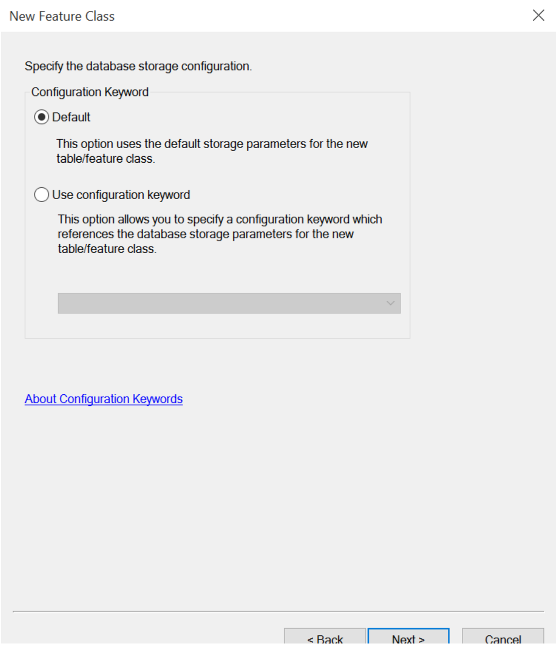


Figure 64: Point database storage configuration

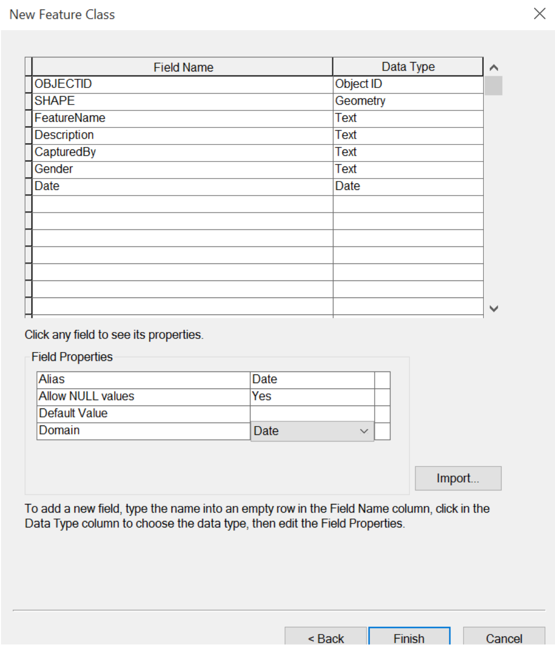


Figure 65: Point feature class fields

Attachments

Attachments were enabled by right clicking on each feature class.

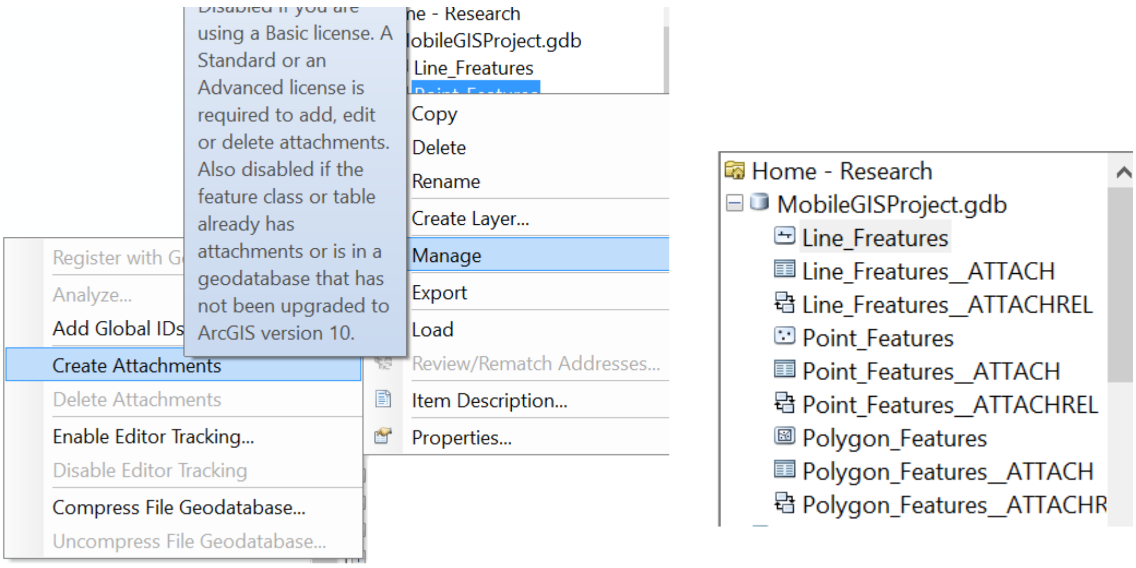


Figure 66: Creating attachments

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.

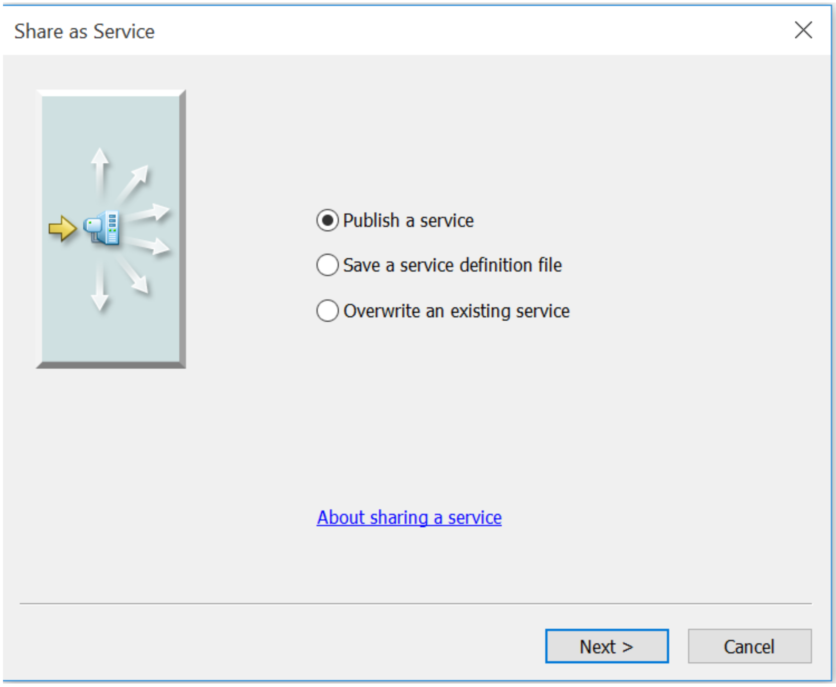


Figure 67: Publishing the mobile GIS project

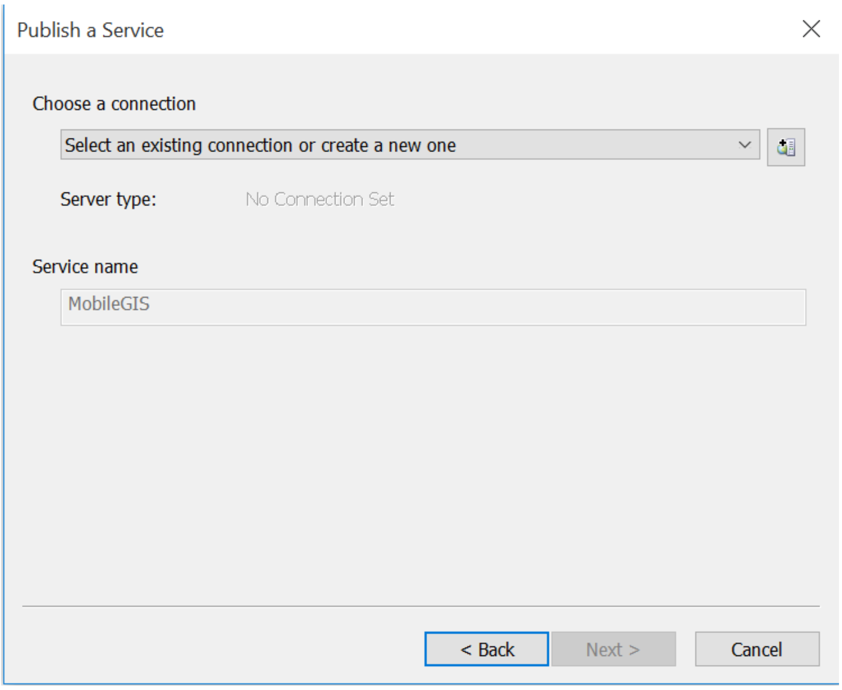


Figure 68: Selecting an existing ArcGIS Online connection

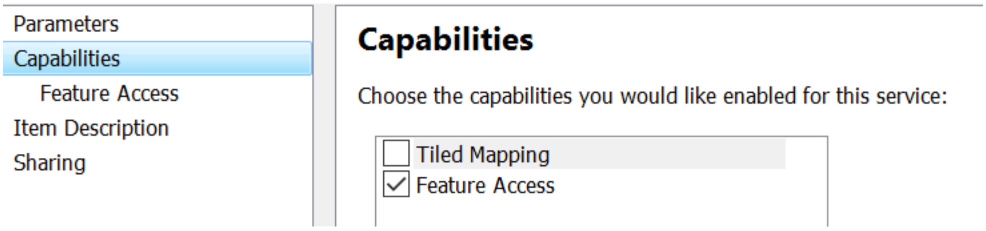


Figure 69: Publishing MobileGIS with feature access capabilities

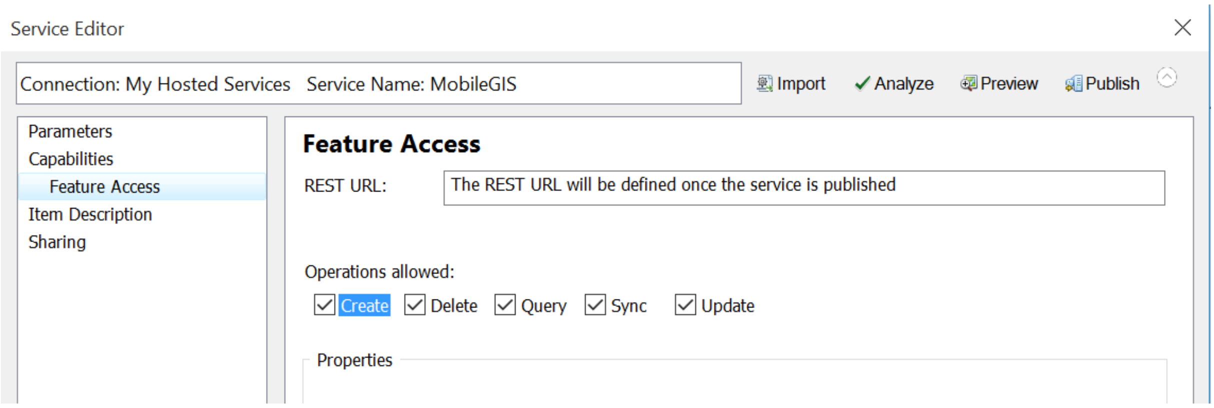


Figure 70: Enabling all operations on MobileGIS

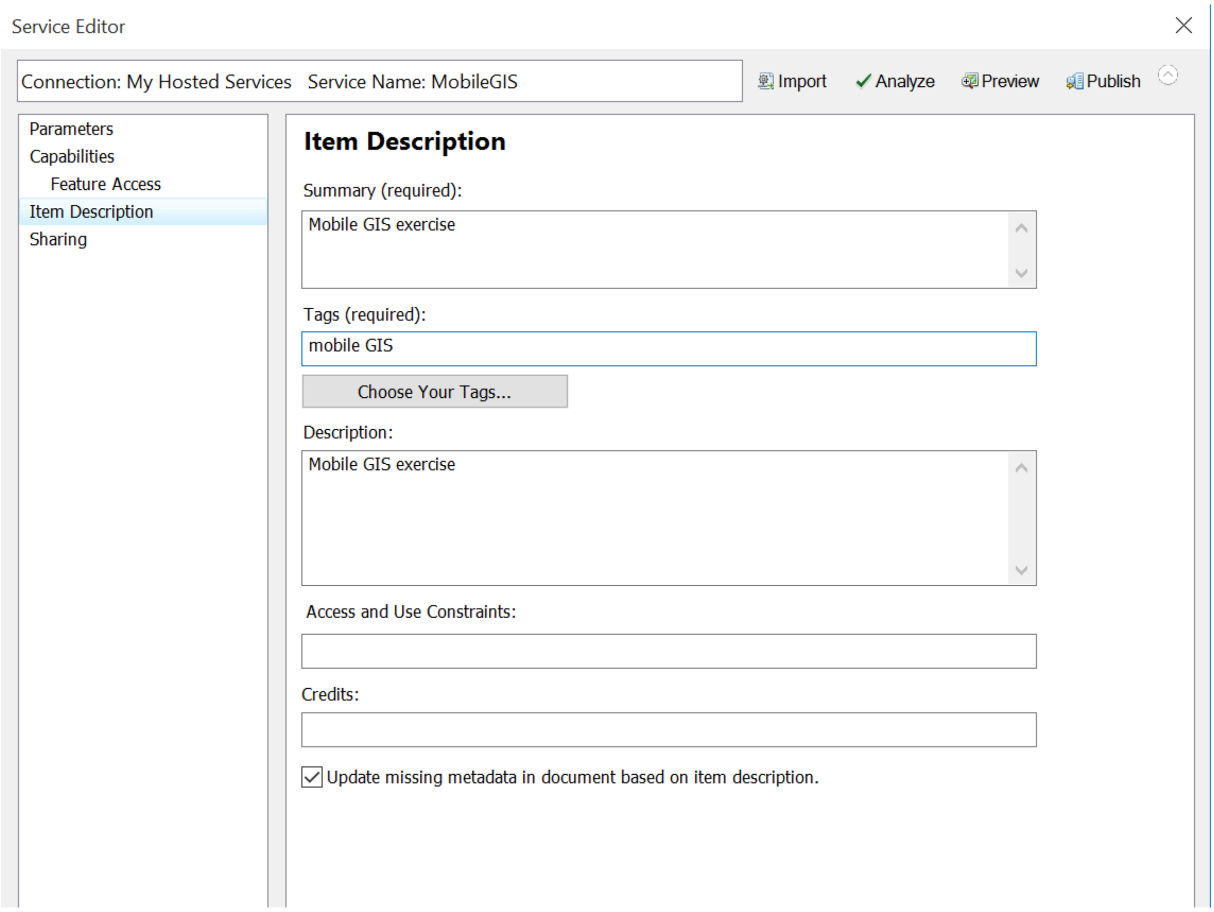


Figure 71: Providing MobileGIS tags and description

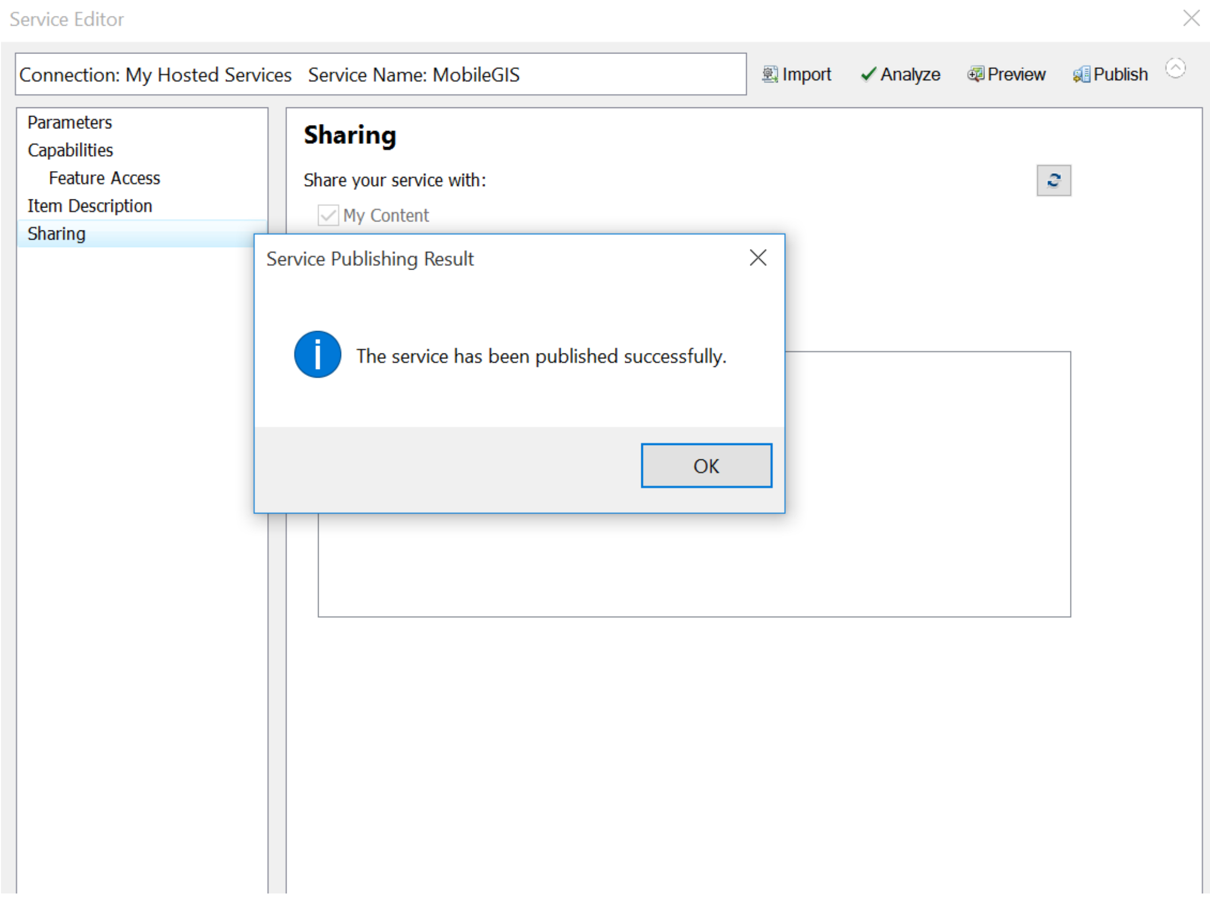


Figure 72: Successfully publishing the service on ArcGIS Online

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.

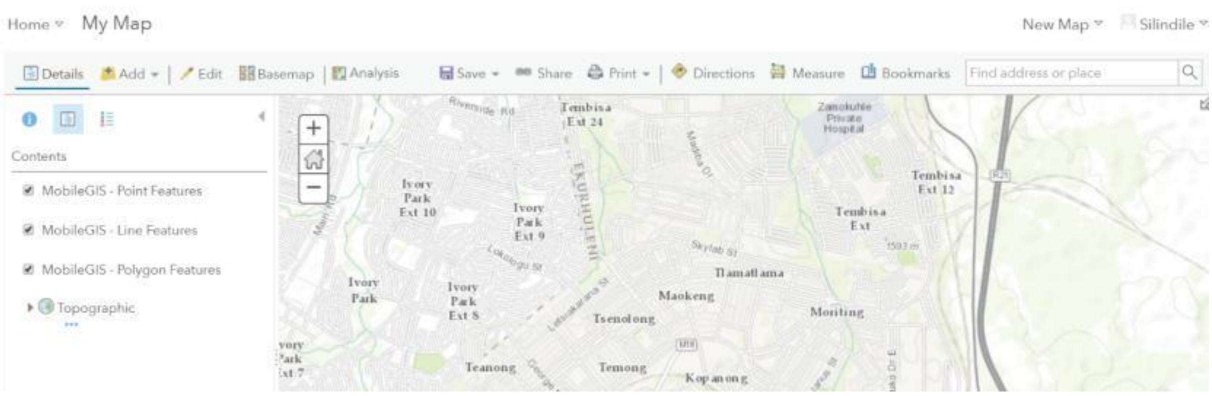


Figure 73: Service on ArcGIS Online

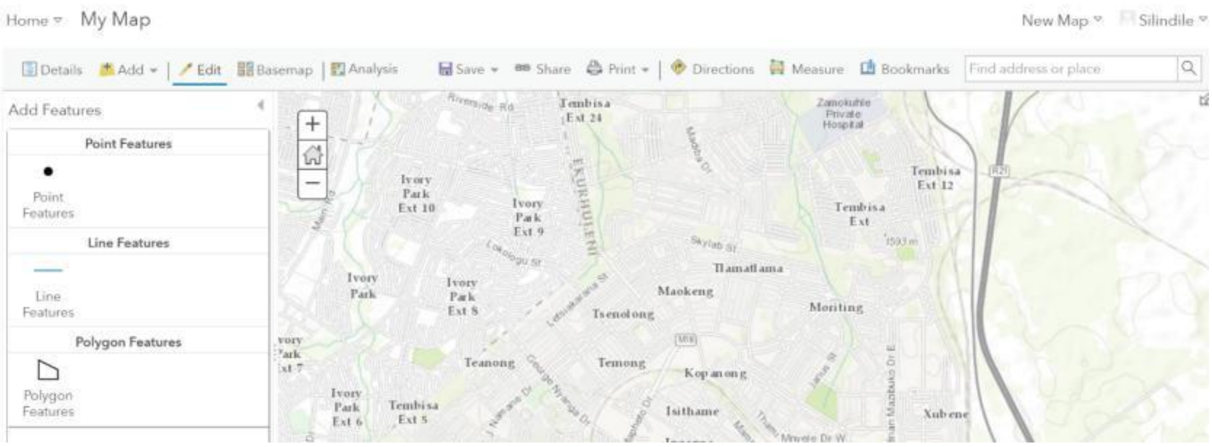


Figure 74: Editable features on ArcGIS Online

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.

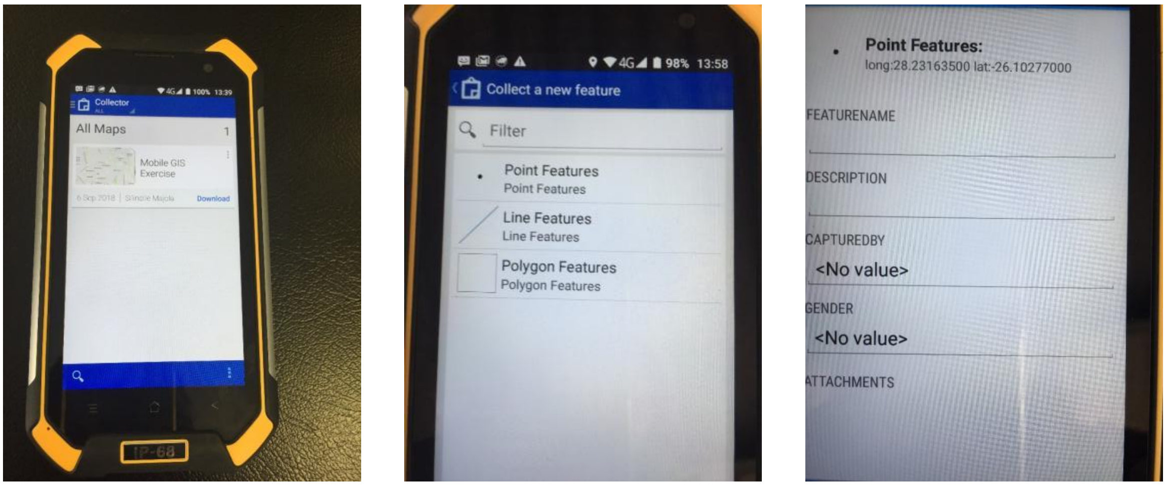


Figure 75: Mobile GIS Exercise map, features to be captured and attributes

Collected data

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

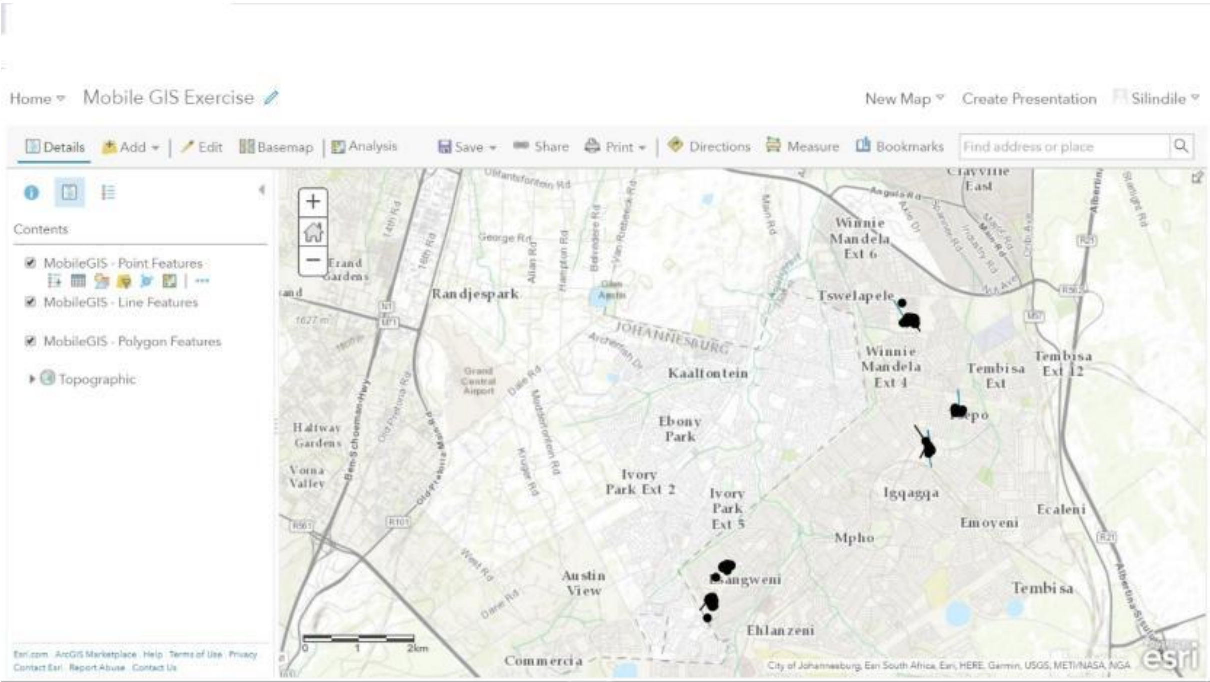


Figure 76: Captured data on ArcGIS Online

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

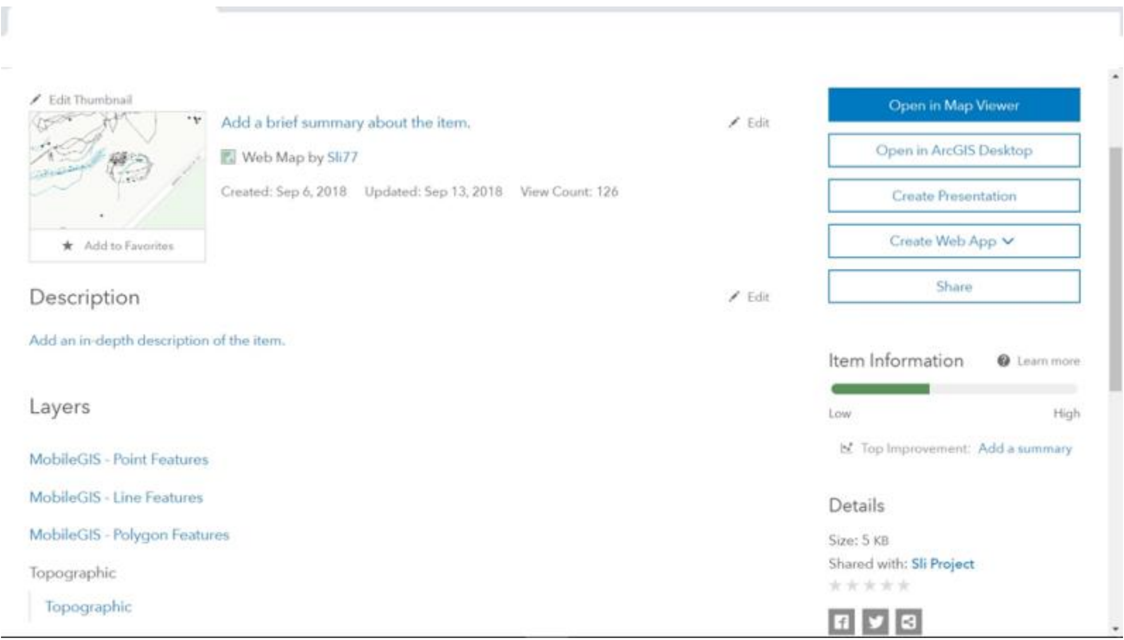


Figure 77: Captured data on ArcGIS Online to be opened in ArcMap

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

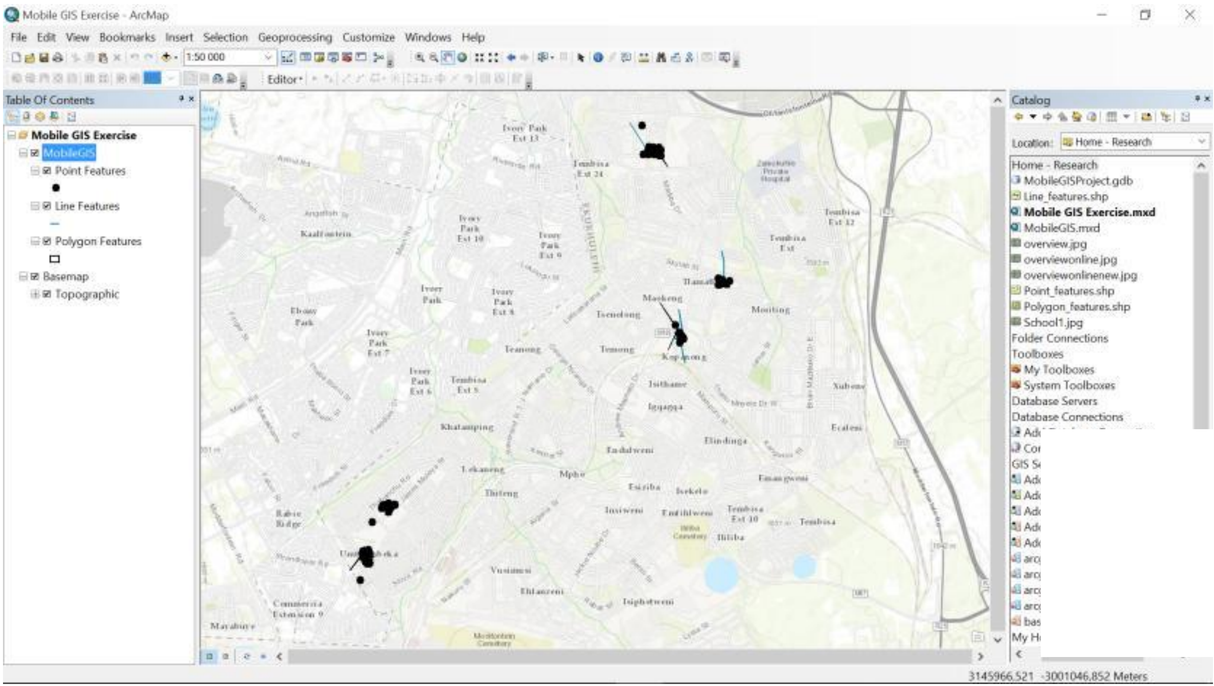


Figure 79: Captured data opened in ArcMap

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.

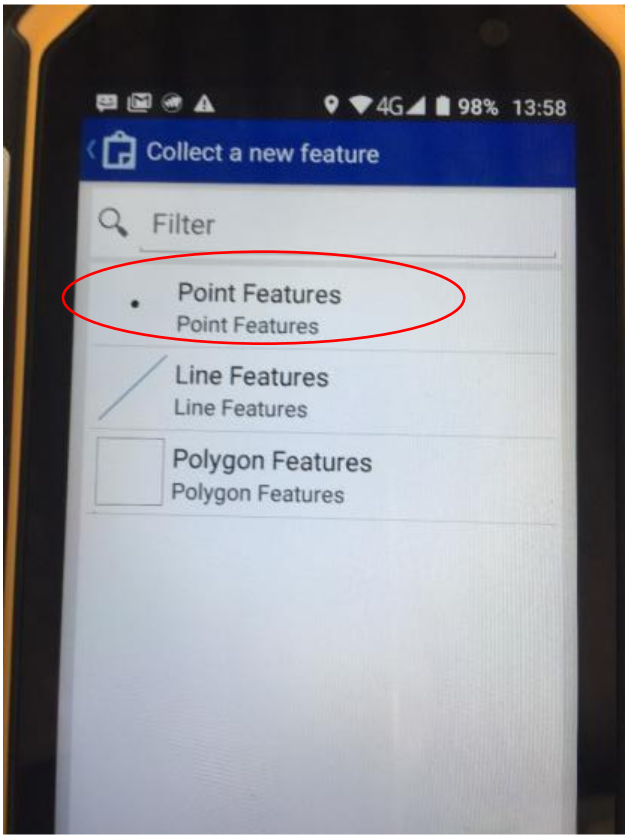
With the map open, you are ready to capture point, line and polygon features within the school premises.

Below are the instructions of how to capture these features:

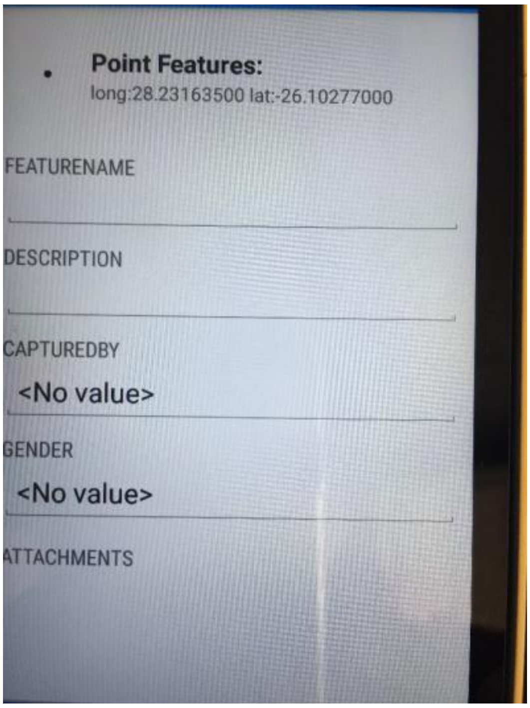
1. Point features

1.1 Select + **Collect a New Feature**.

1.2 Select Point Features circled in red as shown in the image below.

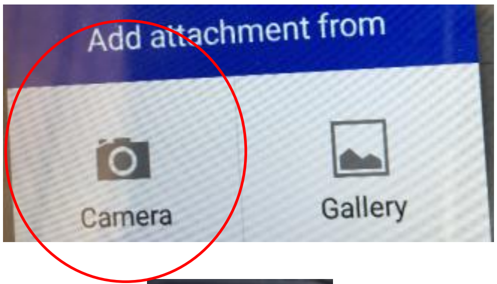


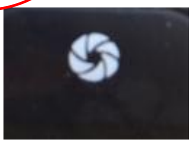
1.3 Wait until you see the coordinates in long and lat then complete the form in the image below by populating these fields: FeatureName, Description, CapturedBy, Gender.



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

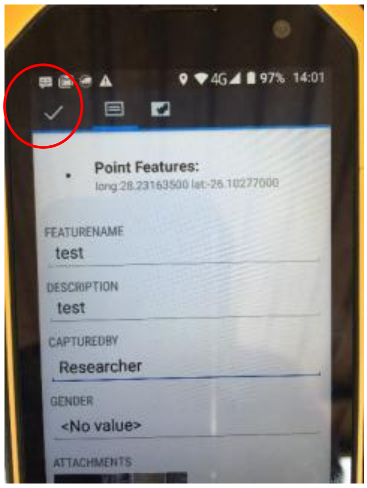
1.5 Then select add attachment from camera as shown in the image below.



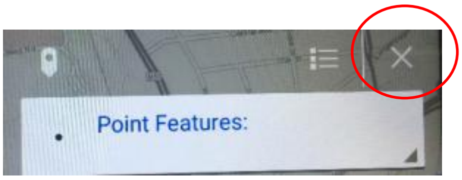
1.6 Press  to take a picture.

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.



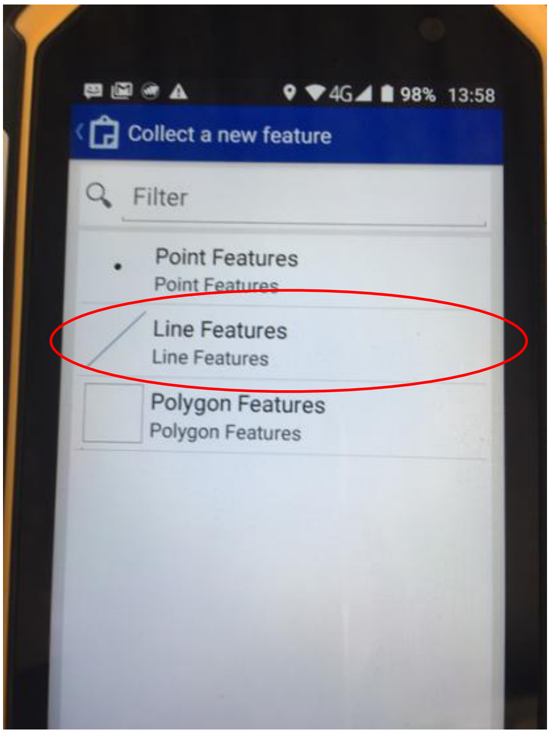
1.9 Close the captured point features in the button circled in red.



2. Line features

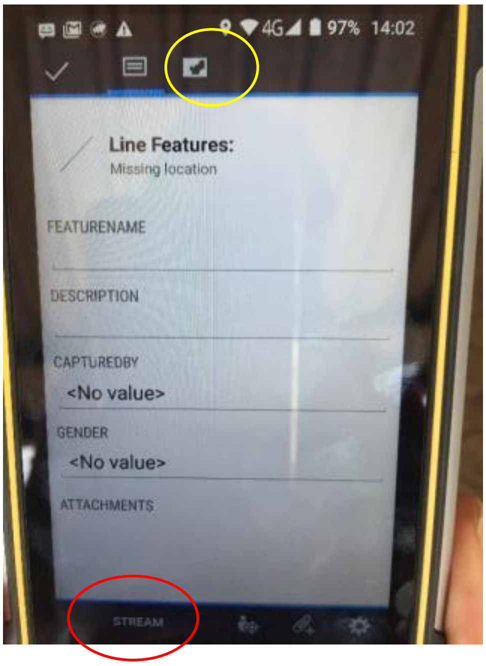
2.1 Select **Collect a New Feature**.

2.2 Select Line Features circled in red below.



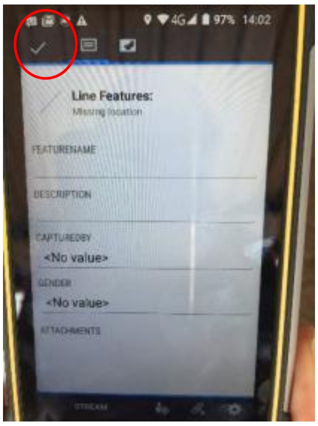
2.3 Complete the form by populating these fields: FeatureName, Description, CapturedBy, Gender.

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



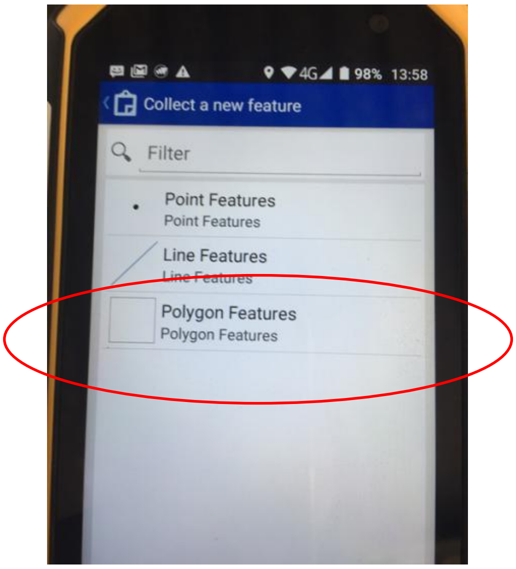
2.7 Close the captured line features in the button circled in red as shown in the image below

Please refer to steps 1.4 to 1.7 if you want to take a picture.

3. Polygon features

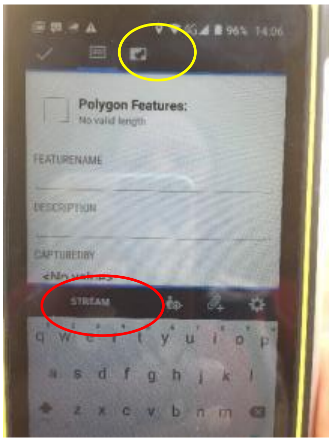
3.1 Select + **Collect a New Feature**.

3.2 Select Polygon Features circled in red below.



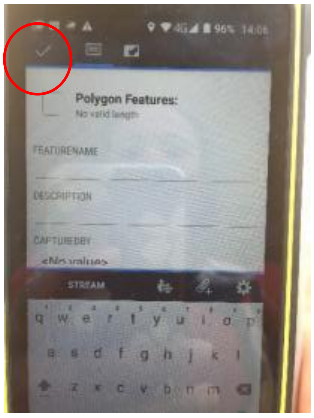
3.3 Complete the form by populating these fields: FeatureName, Description, CapturedBy, Gender.

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.

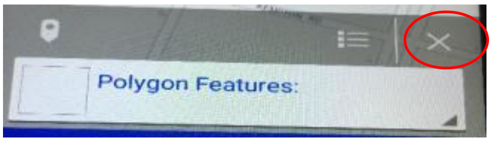


3.5 Start walking following the pattern of the polygon feature that you are capturing. When capturing a polygon your end point will be where you started walking/ capturing.

3.6 When you get to the end point click the tick circled in red as shown in the image below to finish capturing.



3.7 Close the captured polygon 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.

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

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**27 August 2018**
Validity of Research Approval:	**05 February 2018 – 28 September 2018** **2018/261**
Name of Researcher:	**Majola SBNK**
Address of Researcher:	**PO Box 62290**
	Marshaltown
	2107
Telephone Number:	
Email address:	**silindile@hotmail.com**
Research Topic:	**An investigation of the application of GIS in secondary schools: A case study of Grade 11 students in Tembisa, Gauteng South Africa**
Type of qualification	**Masters**
Number and type of schools:	**Six Secondary Schools**
District/s/HO	**Ekurhuleni North.**

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:

27/08/2018

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.
2. The District/Head Office Senior Manager/s 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 researcher/s 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 Office Senior Managers of the schools and districts/offices concerned, respectively.
5. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons 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 researcher/s 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 concluded before the beginning of the last quarter of the academic year. If incomplete, 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.
9. It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.
10. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.
11. 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.
12. On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.
13. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.
14. 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 Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 27/08/2018

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UNIGIS International
Educating GIS Professionals Worldwide

UNIVERSITY of SALZBURG

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ATU57532824

Salzburg, May 2, 2018

CONFIRMATION

On behalf of UNIGIS International, we the UNIGIS office in Salzburg, Austria confirm that **Silindile 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

UNIVERSITÄT SALZBURG
Hellbrunnerstraße 34, 5020 Salzburg

Regina Hatheier-Stampfl