UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

MASTER OF SCIENCE

DISSERTATION

The status of GIS teaching in South African secondary schools including an evaluation of Free and Open Source Software for Geospatial (FOSS4G) using QGIS software and OpenStreetMap (OSM) data as teaching interventions

Bridget Fleming

Student number: 8903577T

Supervisor: Dr Mary Evans

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List of Abbreviations

BOD: Bring Own Device

CAPS: Curriculum and Assessment Policy Statement

CHE: Council on Higher Education

DBE: Department of Basic Education

ESRI: Environmental Systems Research Institute

FET: Further Education and Training (grade 10 to 12)

FOSS: Free and Open Source Software

FOSS4G: Free and Open Source Software for Geospatial

GIS: Geographic Information Systems

GISSA: GIS Society of South Africa

GPS: Global Positioning Systems

ICT: Information and Communication Technology

IEB: Independent Exam Board

IGIST: Interactive GIS Tutor

NSC: National Senior Certificate

ORT: One Research Task

OSM: Open Street Maps

PBL: Project Based Learning

SAGTA: Southern African Geography Teachers Association

SAGs: Subject Assessment Guidelines

SWOT: Strengths Weaknesses Opportunities and Threats

UNESCO: United Nations Educational, Scientific and Cultural Organisation

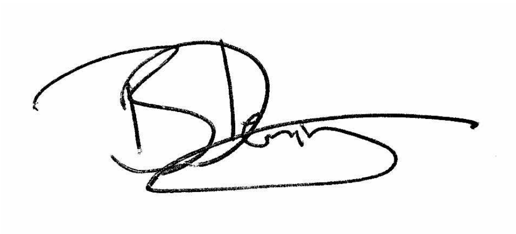
Abstract

South Africa is one of only a few countries that has Geographic Information Systems (GIS) in the secondary school curriculum. Of these few, SA is even more singular as its Geography syllabus includes GIS geoprocessing. The status of GIS teaching in secondary schools is investigated with the aim to determine if the use of Open Source software and data such as QGIS and OSM would facilitate the use of GIS as a teacher intervention. The data was collected by means of an online questionnaire and a smaller sample was interviewed. Results from this study show that only a minority of teachers teach practical GIS classes irrespective of their Examination Board, access to hardware, how resourced their school is or whether they teach at a private or a government school. The key determinants to teaching practical GIS lessons are the teacher's perceived GIS expertise and access to GIS data and time. Software, connectivity, and power supply were also identified as challenges.

Teachers who participated in the study overwhelming agree that there are numerous benefits to using GIS in the classroom. They also expressed a keen willingness to attend GIS courses and learn more about FOSS4G tools. A sample group evaluated how OSM could be used to create local GIS spatial data and how QGIS can be used to teach the GIS curriculum and used to map local data for individual research projects. FOSS4G empowers teachers with the means to create exciting, real, and relevant teaching content that can be used on all platforms, especially in online teaching, if required. There is an urgent need for more current research, both globally and locally, into how GIS can be used more in secondary school pedagogy.

Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



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(Signature of candidate)

20th day of February 2021 at Randburg, Johannesburg

Dedication

To my family:

Husband Gavin

and sons Warren and Gordon

for their constant support and reassurance

Acknowledgments

I wish to acknowledge and thank St John's College for financial assistance, SAGTA for permission to distribute the questionnaire for this research on their social media page and the schools and teachers who participated.

I also wish to thank my supervisor Dr Mary Evans for her guidance and constant encouragement and Jade Brazington for editing.

Chapter 1 Introduction

A Geographic Information System (GIS) performs the function of visualisation, analysing and managing spatial map features in a database. "The use of GIS is attracting growing global enthusiasm among scholars and in the scientific world" (Mzuza & Van Der Westhuizen, 2019, p.175). GIS was introduced as a term in the 1960s and this created a demand for training and education in the use of specialist software (Milson *et al*., 2012). Interest in the educational uses of GIS has mirrored society's overall interest in spatial technologies, especially with the increased demand for consumer-oriented devices and services and the ubiquitous use of social media such as Facebook and Twitter (Riihelä & Mäki, 2015). Recently, Anunti *et al*. (2020) commented that the development of new technological tools and increasing access to GIS resources require more flexible and alternative approaches to teaching about GIS overall and particularly in secondary education. A considerable amount of literature has been published on how GIS is increasingly recognised as a critical 21st century skill that motivates student learning and enhances spatial thinking skills at secondary school level (see Kerski *et al*., 2013; Tabor & Harrington Jr, 2014; Riihelä & Mäki, 2015; Bearman *et al*., 2016; Rickles, 2017; Healy & Walshe, 2019; Anunti *et al*., 2020).

Recently, researchers have shown an increased interest in GIS as a tool to teach the Geography curriculum (Mzuza & Van Der Westhuizen, 2019; Digan, 2019; Collins & Mitchell, 2019; Healy & Walshe, 2020). "The Geography curriculum should encourage students and teachers to use GIS in every phase of high school Geography, with a focus on higher-order thinking skills" (Artvinli & Martinha, 2014, p.136). Studies show that GIS used in the classroom environment can increase students' interest and increase their inclination to technology (Scheepers, 2009; Madsen, 2012; Komlenović *et al.*, 2013; Artvinli & Martinha, 2014; Degirmenci, 2018). GIS helps students "think critically, use authentic data, and connect them to their own community" (Baker *et al.* 2012, p.255). GIS has reached a new phase in its technical development where teachers are no longer limited by what the GIS software can do and instead they can develop the critical spatial thinking aspects of Geography that GIS provides (Bearman *et al.*, 2016)

However, there is very little published research on FOSS4G (Free and Open Source Software for Geospatial) and OSM (OpenStreetMap) data in the classroom. The use of FOSS4G in GIS education provides several advantages, but at the same time introduces challenges (Ciolli *et al*., 2017). Ciolli *et al*. (2017) was one of the only studies found that researched FOSS4G. It concluded that the newer GIS interfaces and the fact that it was no longer perceived to be only command line, made it more accessible for educators to use. The research to date has tended to focus on FOSS4G at tertiary rather than at secondary level (Tsou & Smith, 2011; Sinha *et al*., 2016; Holler, 2019). Mzuza and Van Der Westhuizen (2019) states that the lack of published research is one of the shortcomings that have been observed in the use of GIS globally. This study also emphasised that GIS studies are rare in southern Africa and confirmed the serious need for local studies of GIS applications in secondary schools in southern Africa (Mzuza & Van Der Westhuizen, 2019). The benefits of using FOSS4G in South African schools has not been researched in any of the recent literature.

1.2 Aim

The aim of this research is to determine the status of the teaching of GIS in secondary schools in South Africa with respect to teacher skills and resources available. Furthermore, to evaluate whether FOSS4G, namely open-source software (QGIS) and open data (OSM) would be effective teacher interventions in South African schools.

1.3 Objectives

The objectives of this research were:

1) To establish how GIS is taught in the senior phase (grade 10 to 12) of Geography in secondary schools and determine the exposure students have to practical hands-on GIS through a desktop study of the Geography CAPs and IEB Subject Assessment Guidelines (SAGs) and by conducting an online survey with teachers.
2) To assess the resources available to teachers and schools with which to teach GIS, through the same quantitative online teacher survey.
3) To determine teacher GIS skills level and their perceptions of teaching GIS using the same online survey.
4) To evaluate FOSS4G with QGIS software and OSM data as a teacher intervention by conducting qualitative research by interviewing a sample group of teachers.

1.4 Rationale

Literature published in the last decade indicates that GIS-based teaching has a positive impact on students' achievements and motivation to learn Geography (Madsen, 2012; Kerski *et al*., 2013; Komlenović *et al*., 2013; Fleischmann & van der Westhuizen, 2015; Singh *et al*., 2016; Degirmenci, 2018; Hong & Melville, 2018; Healy & Walshe, 2019; Anunti *et al*., 2020). In South Africa, GIS-based teaching is not common and the map skill section in the curriculum is poorly understood (Innes, 2009; Wilmot & Dube, 2016). The average result for the GIS question in 2018 in Paper Two, the final map skill practical grade 12 Geography assessment, for the 2018 NSC (National Senior Certificate) was 35% (DBE, 2018). Some provinces (such as KZN) had candidates failing to attempt to answer the GIS question altogether (DBE, 2018)Both the Department of Basic Education (DBE) and the Independent Examination Board (IEB) saw a decline in Geography Paper Two results last year (Umalusi, 2020). The DBE has proposed doing away with Paper Two completely and assessing map skills as part of the theory paper as a means to improve these results (SAGTA Conference Proceedings, 2019). DBE examiners commented that "teachers must be trained in mapwork calculation techniques and GIS. Teachers should not only teach the GIS concepts but also the application and relevance thereof in real world situations" (DBE, 2018, p. 83).

There is a body of literature available (Demirci, 2009; Scheepers, 2009; Innes, 2009; Breetzke *et al.,* 2011; Eksteen *et al.,* 2012; duPlessis, 2012) that covers research on GIS at secondary school level when GIS was first introduced in 2006, and later when it was revised in CAPS (Fleming, 2013; Kerski, 2013), yet very few papers on the subject have been published since (Fleischmann, 2017; Mzuza & Van Der Westhuizen, 2019). Here, the status of GIS teaching in secondary schools is investigated with the aim to determine the possible reasons for the lack of GIS practical lessons being taught.

Several studies have revealed that there are many benefits to incorporating GIS into the secondary school curriculum Aladag, 2014; Hysenaj, 2015; Riihelä & Mäki, 2015; Singh et al., 2016; Walford, 2017; Digan, 2019; Anunti *et al*., 2020. The most commonly discussed benefit in the literature is that GIS enhances teaching and learning in Geography by developing spatial literacy and critical thinking skills and this study supports this view (Kerski *et al*., 2012; Wilmot & Dube, 2016; Healy & Walshe, 2019). From as early as 2006 to the present, Geography teachers avoid using GIS in the classroom and the reasons for this are explored here (Kidman, 2006; Demirci, 2009; Lateh & Muniandy, 2010; Komlenović*et al*., 2013; Kerski et al., 2013; Lay *et al*., 2013; Aladag, 2014; Degirmenci, 2018; Healy & Walshe, 2020).

This study is important as it will use FOSS4G software such as QGIS (QGIS, 2019) which is free or *libre* in that there is no cost to download the software and the software code is freely available. This has the benefit of making it accessible to all schools. Researchers found that organisations faced problems with data acquisition when implementing GIS (Lateh & Muniandy, 2010; Osaci-Costache *et al*., 2017). The FOSS4G GIS data that will be used is OSM which is crowd sourced open data that is also freely available online and easy to access (Ciolli *et al*., 2017).

1.5 Ethical considerations

The online survey required teachers to give consent by submission (Appendix C) and no identifying information such as teachers' names, names of schools or emails were collected. Only a sample of teachers from private schools were asked to participate in the interviews as they did not require DBE Departmental permissions. However, these private schools covered both the IEB and DBE Examination Boards. Teachers were interviewed in their individual capacity as experts in their field. Heads of Schools were contacted prior to all the interviews and written permission to conduct the study was received. Teachers participating in the research were asked for consent and permission to use the data from surveys and interviews and consent letters were signed (Appendix A). The respondents were informed that there was no remuneration and no benefit received from their participation. Confidentiality was guaranteed. For the online surveys, consent was given through participation. All schools and teachers were allocated a letter from A to I to assure anonymity and to allow candidates involved in the research more freedom of expression when answering questionnaires. The online survey and interviews took place in October 2019 to March 2020, after ethics approval was granted by the Human Research Ethics Committee (non-medical) of the University of the Witwatersrand, protocol number H19/09/09 (Appendix B).

1.6 Outline of the Report

Chapter 1: Introduction covering the aim; objectives; rationale; ethical considerations and the outline.

Chapter 2: Literature review introduction; GIS in secondary school education; FOSS4G software and data as a GIS teaching tool; global context of teaching GIS in schools; Global teacher interventions for GIS in schools and case studies of teaching GIS in the classroom; Background to GIS in South Africa and teacher interventions for GIS in South Africa.

Chapter 3: Methodology covering why the mix-methods approach was adopted; quantitative data collection; analysing the quantitative data and qualitative data collection and verification.

Chapter 4: Results for the online survey covering the demographics of the participants; the type of school the participants teach in and the GIS-enabling resources available; how GIS is taught in the classroom; the level of teacher GIS experience and skills and research results for the interviews conducted and the identified themes.

Chapter 5: Discussion of who the respondents are; how prepared the teachers are to teach GIS; what GIS-enabling resources do teachers have access to and what would teachers like to have access to;

what the advantages and challenges are of teaching GIS in the classroom; what the feasibility is of using FOSS4G tools in the Geography classroom and what is the future of GIS education.

Chapter 6: Conclusion, recommendation and further research, reflections and limitations

Chapter 2 Literature Review

2.1 Overview

The "G" part of GIS refers to physical map features, stored as points, lines, polygons (vector data), or images (raster data). The "I" component of GIS refers to the database behind the map. The "G" and "I" are integrated into the "S" part of GIS – the system, so that asking a spatial question on the map simultaneously asks the same question of the database, and vice versa (Milson *et al.*, 2012). The emergence of the Internet in the late 1980s and later the World Wide Web (www) in the mid-1990s resulted in GIS becoming used more in research and in solving spatial problems (Tate & Jarvis, 2017; Walford, 2017; Degirmenci, 2018). Geography, which is fundamentally an earth science subject that focuses on both the human and the physical aspects, lends itself to GIS as it looks at spatial relationships in the physical and human environments.

Today earth scientists perceive GIS as a powerful mainstream technology in various web-based maps such as Google Earth, position allocation devices such as Global Positioning System (GPS) and remote sensing technologies (Hysenaj, 2015). In recent years, there has been an increasing amount of literature on the benefits of teaching GIS in the classroom for the understanding of geographical knowledge and to help teach the curriculum (Degirmenci, 2018; Hong & Melville, 2018; Holler, 2019; Collins & Mitchell, 2019; Mzuza & Van Der Westhuizen, 2019; Digan, 2019; Healy & Walshe, 2020; Zondi & Tarisayi, 2020; Anunti *et al.*, 2020). Mzuza and van der Westhuizen (2019) refer to GIS becoming indispensable, because it will be difficult to solve or sort out problems without it. They continue by making the point that soon the necessity to include GIS in secondary school education cannot be disregarded any longer, as a knowledge of GIS will be essential in future.

Twenty years ago Audet and Ludwig (2000) said that a classroom that uses GIS as a problem-solving tool is a classroom in which 'the walls are invisible and the teacher and student assume roles that are non-traditional'. They go on to say that incorporating GIS into the classroom is not for the fainthearted and that integrating GIS into the curriculum rewards teachers by creating intellectually challenging and demanding learning opportunities (Audet & Ludwig, 2000). The current literature reviewed collectively echoes their sentiments.

This review is a chronological summary of how GIS was introduced into the secondary school education curriculum both globally and in South Africa. Some of the core GIS skills that are required to teach GIS are described along with some successes and failings of teaching GIS in the secondary school classroom.

2.2 GIS in Secondary School Education

Traditionally, it has been argued that the main focus was to only train students to use GIS software in more formal degree programmes leading to undergraduate and postgraduate GIS qualifications (Kerski *et al*., 2012; Tate & Jarvis, 2017; Walford, 2017). There has been a global increase in GIS use in secondary schools over the last ten years mainly due to the perceived benefits it provides to learning (Rickles, 2017; Healy, 2019; Digan, 2019).

here is a consensus among researchers that incorporating GIS into lessons at secondary school level allowed for greater analysis of data that students collected in the field and enhanced their spatial thinking (Aladag, 2014; Riihelä & Mäki, 2015; Singh *et al.,* 2016; Stonier & Hong, 2016; Millsaps & Harrington Jr, 2017; Digan, 2019; Anunti *et al.,* 2020). It has also been demonstrated that students who have the opportunity to use modern teaching aids such as GIS in the learning process develop geographic knowledge, skills and attitudes more effectively (Komlenović *et al*., 2013; Hysenaj, 2015; Walford, 2017). Singh *et al.* (2016) found that GIS-based teaching in the Geography classroom had a more positive effect on students' motivation and achievement levels compared to traditional teaching methods. Portugal and Finland adopted a student-centred approach and support GIS material has been funded by their respective Ministries of Education to provide teachers with resources to teach the Geography curriculum through GIS (Artvinli, 2014; Anunti *et al*., 2020). Furthermore, Anunti *et al*. (2020) concluded in their research that a teacher-centred approach for teaching about GIS in secondary schools was also considered to be very important. The research findings strongly indicate that a teacher is needed to guide the student-centred learning process no matter how good the GIS resources are (Anunti *et al.,* 2020, p.278).

Much of the current global literature on GIS in secondary school education referred to ArcGIS, proprietary software from ESRI (Environmental Systems Research Institute). ESRI is an international supplier of geographic information system (GIS) software (ESRI, 2020). A number of studies have published case studies using GIS in the classroom, all of which used ArcGIS software: Digan (2019) looked at the inclusion of GIS in the Australian Curriculum; Hong & Melville(2018) researched teaching social studies using GIS in Georgia , USA; Healy & Walshe (2020) studied how a programme of GIS training was integrated within a two-year A-Level examination course in the United Kingdom and Tabor & Harrington (2014) examined how GIS improved spatial literacy in the K-12 social studies school curriculum in Kansas, USA. All of these studies were conducted in more economically developed countries that had sufficient access to funds to pay for ESRI GIS licenses albeit at a subsidised price for education institutions.

Proper training for teachers at secondary school level is important as it would give teachers the confidence to use GIS to teach the curriculum and to use GIS more in project-based learning (Baker *et al.,* 2012; Fleming, 2016; Hong & Melville, 2018). This research and others have shown that teachers identify the lack of GIS training at secondary level as one of the biggest hurdles to teaching GIS (Eksteen *et al*., 2012; Zondi & Tarisayi, 2020).

2.3 FOSS4G software and open data as a GIS teaching tool

The use of FOSS4G (Free and Open Source Software for Geospatial) software and open data in education has been addressed in several small-scale investigations (Sinha *et al*., 2016; Ciolli *et al*., 2017; Holler, 2019). The comparative lack of research into FOSS4G software and data may be because the use of the OSM QGIS plugin is very recent (2014 - 2020) (Trimaille, 2014). Studies of the use of OSM in education are yet to be published. Muenchow (2019) looked at how FOSS4G could be used in qualitative research and found that a large body of studies lacked clear information on the software packages used and that the share of FOSS4G is negligible. This study was more applicable to using GIS as a research tool at tertiary education institutions and the authors concluded that research is lacking in the use of FOSS4G in qualitative research (Muenchow, 2019).

ate & Jarvis (2017) discussed the concept of "big data" and the use of open data in GIS teaching. The emergence of geospatial Massive Online Open Courses (MOOCs) has allowed educators to be innovative in how local data sets can be acquired (Tate & Jarvis, 2017). Both Tate & Jarvis (2017) and Healy & Walshe (2019) emphasised that the curriculum needs to accommodate new technologies to reflect the needs of the developing discipline of GIS. Milson *et al*. (2012) concluded before Tate & Jarvis (2017) and Healy & Walshes' (2019) research that "a frequently mentioned constraint to the implementation of GIS is the lack of available spatial data in many countries. The trend toward Open Data policies will increase the number of schools that can use that data and hence make it easier to teach with it" (Milson *et al.,* 2012 p.318). A common theme in the literature is the challenge of finding suitable GIS data, experienced by educators who are engaging students in spatial thinking and analysis. The ease of accessibility and use of Open Data as a solution to this challenge is mentioned in more recent publications (Sinha *et al*., 2016; Fleming, 2016; Ciolli *et al.*, 2017; Holler, 2019; Anunti *et al*., 2020).

A White Paper on Open Source GIS software for GIS education from the National geospatial technology Center of Excellence (USA) was made available to the global community (Tsou & Smith, 2011). Even though this paper is not recent, many of the Open-Source software options mentioned in the White Paper such as gvSIG, GRASS and Quantum, GIS which is now called QGIS, are still available today. This is important as this paper makes an appeal to GIS educators to realise the potential of open-source GIS software for their courses and instructional tools. Most of the FOSS4G discussed in Tsou's paper have been improved on significantly, namely QGIS software. FOSS4G technologies have far more functionality and are more user friendly than they were in the past (Holler, 2019). Henrico *et al.* (2020) expands on this in his recent paper presented at the 2019 FOSS4G International Conference. The White Paper acknowledges that the road to adopt Open-Source GIS (FOSS4G) may not necessarily be smooth and quick in comparison to commercial solutions but it is more affordable and that it offers customisation of the software for students' needs (Tsou & Smith, 2011).

A study of 154 undergraduate and master students at the University of Bucharest who all used both proprietary and Open-Source GIS software provided useful information (Osaci-Costache *et al*., 2017). This study concluded that the use of QGIS open-source software was beneficial for three reasons:

- The software is free which is an advantage for both the students and the university.
- The software can be used legally both at the university and at home.
- The software is efficient and meets the needs of the students.

Osaci-Costache *et al.* (2017) also concluded from their study that the rapid development of GIS Open-Source tools compelled the students to adapt, although this was also a reason that some students were reluctant to give up proprietary software and move over to Open Source. (Henrico *et al*., 2020) found similar findings in her research to that of Osaci-Costache *et al.* and described that the results of her study show that habit, facilitating conditions, price value and social influence have the most significant influence on behavioural intention to use QGIS by GIS practitioners.

Ciolli *et al.(*2017) examined the last twenty years of using GIS in education at two Italian universities and how even with an open source software for geospatial (FOSS4G) approach, the management of educational materials can be difficult for students. This study concluded that the development of educational material using FOSS4G for use in the classroom requires a large amount of time invested by a skilled person who is familiar with the principles and procedures of spatial data management and analysis and at the same time has experience of teaching geographic topics. This research and others further advocate that FOSS4G be encouraged for ethical implications as it supports the user community and it does not lock students into using expensive proprietary software (Ciolli *et al*., 2017; Osaci-Costache *et al*., 2017; Holler, 2019).

Finnish schools are now replacing desktop GIS with online GIS (Riihelä & Mäki, 2015). From 2016 the national examinations were written online, and Geography was chosen as the first subject to be assessed online. This allowed for GIS to be integrated into the assessment tool. Finland's "PaikkaOppi" project used open-source software and open data (Riihelä & Mäki, 2015). The success of its implementation is yet to be established. Recently, Anunti *et al*. (2020), took Riihelä and Mäkis' (2015) study further and determined how effective using a portfolio model to teach GIS in Finnish schools was and concluded that the use of a digital GIS portfolio is a promising pedagogical method in GIS education. This study used Open data with Esri Online map layers (Anunti *et al*., 2020).

Holler's (2019) paper explains how QGIS can be used effectively in Higher Education. The course content Holler used is summarised below (Holler, 2019, p. 100):

- Understand, use, and articulate concepts that are fundamental to a geographical perspective, such as scale, region, location, space, distance, and spatial interaction.
- Critically examine a range of thematic problems and recognise geographic dimensions of contemporary issues. Understand and critique how geographic information systems are used in human Geography research and real-world applications.

- Develop and use basic geographic skills such as map reading, cartography and spatial analysis. Critically interpret and evaluate maps and other forms of location-based data.
- Given geographic questions and data sets, select and implement appropriate methods to answer the questions. Effectively communicate your methods and findings through diagrams, maps, and narrative.
- Become familiar with using geographic information systems and learning new GIS techniques.
- Conduct GIS research.

Holler (2019) concluded that Open-Source code enables a more intimate and technical knowledge of GIS data structures. From the students' perspectives, the most important difference with using FOSS4G is probably the accessibility and freedom afforded by open licences to install and use the technology beyond the spatial limits of GIS labs. This study is important as not only does it illustrate that Open Source GIS can be used in an introductory GIS course, but it enabled students to apply spatial analysis and human geographic theory to help solve social spatial problems. The same course content can be applied to developing a local teachers' course to enable teachers to teach the Geography curriculum using Open-Source GIS (Hysenaj, 2015; Mzuza & Van Der Westhuizen, 2019). Fleischmann and van der Westhuizen (2015) in a separate study also used QGIS in their research in South African schools with grade 11 learners and concluded that their work provided a framework upon which GIS developers, academia, teachers and the Department of Basic Education could collectively develop workable GIS teaching options. The Fleischmann and Van Der Westhuizen (2015) study is significant as it remains one of the few local case studies to use FOSS4G in South Africa.

Sinha *et al*. (2016) referred to the phrase PGIS (Participatory GIS) and the goal of their research was to raise awareness of its potential as an extracurricular source of geographic learning. They concluded that the literature is filled to the brim with academically initiated GIS projects, but the focus on student learning has been conspicuously absent (Sinha *et al.* 2016). The case studies referred to in Sinha's (2016) research used both ESRI and FOSS4G software. There appears to be a need with regards to researching the current use of FOSS4G tools and GIS use in the classroom. Mzuza & Van Der Westhuizen

(2019), Digan (2019), Healy & Walshe (2019) and Anunti *et al* (2020) all make the same concluding remarks in their respective papers, that more research needs to be done on GIS teacher training and use in the classroom.

2.4 Global context of teaching GIS in schools

A considerable amount of literature was published initially when GIS was first mainstreamed and many researchers highlighted the pedological advantages of incorporating GIS in the classroom (Innes, 2009) (Demirci, 2009; Lateh & Muniandy, 2010; Lay & Chen, 2011; Eksteen *et al.,* 2011; Madsen, 2012; Milson *et al*., 2012; Komlenović *et al*., 2013; Kerski *et al.*, 2013). Milson *et al.* (2012) highlighted the importance of inquiry-based teaching, where GIS is the enabling tool that allows students to engage in meaningful issues about their environment, time, and place. GIS education is fundamental to critical thinking and to the creation of decision-makers (Milson *et al*., 2012). This study examined thirty-three case studies, the locations of which are represented in Figure 2-1 plus nine more countries were added to his study after reviewing more recent research (compiled by QGIS).

Figure 2-1: Composite map showing countries where GIS is taught at secondary school level, based on the publications discussed in this chapter (compiled by QGIS).

Since its introduction, GIS in secondary education has been met with a number of challenges. Despite the benefits of teaching GIS, Geography teachers avoid engaging with GIS in their classrooms (Ciolli *et al*., 2017; Healy & Walshe, 2019) and most educators are ill-equipped to teach the GIS section of the curriculum (Innes, 2009; Eksteen *et al.,* 2012; Fleischmann & van der Westhuizen, 2015; Wilmot & Dube, 2016; Zondi & Tarisayi, 2020). A number of researchers found that GIS has not been taught effectively in many other countries, for example Turkey (Demirci, 2009; Aladag, 2014; Artvinli & Martinha, 2014; Degirmenci, 2018) Portugal (Artvinli & Martinha, 2014); Taiwan (Lay & Chen, 2011) Malaysia (Lateh & Munlandy, 2010; Singh *et al.,* 2016); France (Kerski *et al*., 2013); United Kingdom (Bearman *et al.,* 2016; Tate & Jarvis, 2017; Walford, 2017; Healy & Walshe, 2020); USA (Tabor & Harrington Jr, 2014; Stonier & Hong, 2016; Millsaps & Harrington Jr, 2017), Serbia (Komlenović *et al.,* 2013); Rwanda (Akinyemi, 2016); and South Africa (Scheepers, 2009; Breetzke *et al*., 2011; Fleischmann & van der Westhuizen, 2015; Mzuza & Van Der Westhuizen, 2019; Zondi & Tarisayi, 2020), see Figure 2-1.

2.4.1 Global challenges of teaching GIS in schools

There has been extensive research in GIS interventions in schools globally and the most common challenges to teaching GIS in schools are lack of resources, lack of skills, lack of teacher motivation, time constraints, poor curriculum design and the status of Geography at secondary school level (Milson *et al.,* 2012; Kerski *et al.,* 2013; Akinyemi, 2016; Wilmot & Dube, 2016; Fleischmann, 2017; Degirmenci, 2018). Other studies show that Geography teachers are still shying away from using GIS in the classroom because of teachers' negative attitude to adopting GIS. GIS is frequently seen to be too technically complex, too difficult to integrate into an already too busy Geography curriculum or see it as simply impossible to do (Kidman, 2006; Demirci, 2009; Lateh & Muniandy, 2010; Komlenović*et al.,* 2013; Kerski *et al.,* 2013; Lay *et al*., 2013; Aladag, 2014; Degirmenci, 2018; Healy & Walshe, 2020).

The research shows that many challenges are global and span both developed and developing countries. The same challenges are discussed in the research spanning the last twenty years. Current researchers conclude that the lack of published research is one of the numerous shortcomings in the use of GIS in secondary education globally (Hong & Melville, 2018; Mzuza & Van Der Westhuizen, 2019; Holler, 2019; Healy & Walshe, 2020; Zondi & Tarisayi, 2020).

2.4.2 Global case studies of teaching GIS in schools

Surveys such as that conducted by Healy & Walshe (2019) of school students between the ages of 16-17 writing the A-Level UK examinations showed that only two of the fifteen knew what a GIS was. GIS was introduced into the A-level syllabus in 1991 (Komlenović *et al.*, 2013) as part of the Year 12 fieldwork. Healy & Walshe (2019) and Komlenović *et al.* (2013) conclude that there is a need for further research as to how GIS can be effectively embedded into the secondary Geography school curriculum. In another recent study in Turkey, Degirmenci (2018) interviewed fifteen Geography teachers and all agreed on the necessity of using GIS in Geography lessons. Only two teachers in his study had any formal GIS training. GIS was introduced into the Geography curriculum in 2005 in Turkey, a year before it was introduced in South Africa. Degirmenci's (2018) results are similar to that of Akinyemi (2016) in that all teachers interviewed agreed that GIS added value to education. Both studies show that teachers were not competent enough to use GIS technology.

Aladag's (2014) study asked teachers to name the advantages of using GIS in the classroom and they emphasised that it increased spatial literacy, helped develop map information, contributed to "permanency", made learning more enjoyable and improved "usability" in the teaching of many subjects in Geography. Demirci (2011) also looked into the effectiveness of using GIS-based exercises in the classroom in very under-resourced schools in Turkey. His study looked at other barriers to GIS implementation such as lack of hardware, internet access and teacher training (Demirci, 2011).

Taiwan was another early adopter. GIS was included in their senior high school curriculum in 1999 in grade 12 and this was revised in 2006 and 2010 to be included into the grade 10 curriculum so that all Taiwan's high school students are required to learn basic GIS concepts (Lay & Chen, 2011). South Africa followed a similar trend of first introducing GIS into the curriculum in 2006 and revised it again in 2010 (Innes, 2009; Eksteen *et al*., 2011; DBE (South African Department of Basic Education), 2011; Fleischmann & van der Westhuizen, 2015; Wilmot & Dube, 2016; Fleming, 2016).

In Taiwan, Geography teachers were provided with resources, training and assistance in learning GIS. Lay & Chens' (2011) initial study concluded that teachers' willingness to participate in in-service GIS training was affected by the perceived ease of GIS adoption (Lay & Chen, 2011). Two years later in a later paper, Lay *et al.* (2013) looked at how GIS teacher training occurred in Taiwan, the United States, Singapore and Hong Kong. This paper looked at the 2006 and 2010 Geography curriculum guidelines in Taiwan that advocated hands-on GIS experience using GIS software and hardware (Lay *et al*., 2013). Their study examined how GIS knowledge and skills are learnt by Geography teachers and then disseminated to pupils in class. Their study found that teachers were incentivised when they realised that using GIS made teaching Geography concepts easier (Lay *et al*., 2013). Kerski *et al.* (2013) also found this to be so in his study around the same time and agreed that Taiwan pupils had more practical GIS exposure and referred to Lay's case study.

inland also requires pupils to do a practical GIS component in their own research projects at year 12 (Riihelä & Mäki, 2015; Anunti *et al*., 2020). There was a shift from a knowledge-based curriculum to a more skills-based curriculum (Tani, 2014). The Finnish curriculum requires that every pupil be familiar with GIS at an introductory level whether they do Geography as an elective or not. It is seen as part of active citizenship, sustainable technology, communication and media (Tani, 2014; Riihelä & Mäki, 2015; Anunti *et al*., 2020).

Geography is not taught as a separate subject in the United States at secondary school level and in the K-12 system there is concern over the decline of geographic literacy. GIS is incorporated into the following subjects at secondary school level in the United States - English, Social Studies, Mathematics, Physical Science and library/media literacy (Collins & Mitchell, 2019). Introducing GIS into the Social Sciences curriculum in the United States is seen as an innovative way of reinforcing spatial literacy (Tabor & Harrington Jr, 2014). Hong & Melville (2018) looked at the types of support that teachers in the United States needed to develop their own inquiry-based lessons using GIS. The focus group in this study was Social Studies teachers using ArcGIS software. The researchers in this study recommended that GIS professional development be made mandatory if it is to be taught and get teachers to commit to using GIS in the classroom (Hong & Melville, 2018).

It is noteworthy that Kerski *et al.* (2013) found the South African curriculum to be one of the few that required pupils to apply data acquisition, management, manipulation and analysis (Eksteen *et al*., 2012; Kerski *et al*., 2013). Australia, Denmark, Norway, Finland, France, Spain, Germany, Portugal, Japan, Netherlands, New Zealand and Colombia used web GIS applications such as ArcGIS online (Milson *et al*., 2012). Of all the countries studied, Hungary was complimented on their use of incorporating GIS into their fieldwork, going out to collect Global Positioning Systems (GPS) tracks and analysing results of data that the students collected.

2.5 Global teacher interventions for GIS

Professional development workshops provide teachers with increasingly efficient tools for teaching and create enthusiasm for introducing GIS into the classroom (Tabor & Harrington Jr, 2014; Bearman *et al*., 2016). Riihelä & Mäki (2015) refers to five characteristics that are necessary for GIS to be utilised in the classroom and teacher interventions need to take the following into account:

- The GIS software to be used in the classroom should not appear intimidating.
- A teacher should be able to learn the basic features of the tool in one to two hours.

- Learning to operate the GIS software should not get in the way of using it for instructional purposes.
- The geospatial data needed to use the GIS should be pre-processed and included integrally.
- Technical and administrative support should be available as teachers begin to explore the use of GIS in classroom instruction.

Anunti *et al*. (2020) added to Riihelä & Mäkis' (2015) list by concluding that GIS data also needed to be readily accessible to teachers. Furthermore teachers needed training to teach GIS skills and easy-to-use GIS software and readily available instructional material (Anunti *et al.*, 2020).

Another approach discussed in the literature is introducing GIS to teachers through Project Based Learning (PBL) projects. According to Ciolli *et al*. (2017) the most effective GIS education has been carried out via project-oriented teaching also known as project-based learning, an approach that offers integration between theory and practical training (Ciolli *et al*., 2017). ESRI's ArcGIS online was used in a similar study in the United States, training high school teachers in a summer workshop (Stonier & Hong, 2016; Singh *et al*., 2016). Collins and Mitchell's (2019) recent study of what is required in GIS teacher training for the long-term and sustained use of GIS in the classroom was also based in the USA and their research involved a SWOT analysis of their survey. Their questions were organised under the following categories: teacher practices and attitudes, educational technology, professional development and education context for GIS. The analysis for their research was similar to the PBL described by Ciolli (2017). All these studies incorporated an inquiry-based model to collect data and used an online GIS package (ESRI, 2020).

Bearman *et al.* (2015) mainly looked at how GIS could be taught more effectively at tertiary level and many of his findings were similar to that of Riihelä *et al*. (2015) in that GIS software needed to be simple to use. However, Bearman's *et al.* (2015) study added one other key finding that students were resistant to change and innovation from the teaching staff and that students require a certain level of IT skills to make the most effective use of GIS. Another concern noted in Bearman's *et al.* (2016) later research is that students needed set time in the computer labs, but this depended on the software used.

Globally, in-service teacher training was identified as an important teacher intervention. Degirmenci (2018) study showed that a great majority of the teachers did not use the GIS in their lessons and the reason for this was that they do not have sufficient knowledge about how to use them. He observed that all the teachers agreed on the necessity of using GIS in Geography lessons, but they lacked basic training (Degirmenci, 2018). Digan (2019) concurred with Degirmenci (2018) in that they both concluded that teacher training is necessary for teachers to have the necessary skills to provide effective GIS-based lessons. Millsaps *et al*. (2017) developed a framework for in-service GIS training and emphasised that not one size fits all in GIS education and that GIS can work for any teacher, their content, their classroom, and their time availability. This study concluded that convincing teachers to participate in professional development that involves new technology was a challenge (Millsaps & Harrington Jr, 2017). Teachers' attitude to GIS in Rwanda was positive when they had prior GIS training. It was also found that their views differed based on gender (Akinyemi, 2016).

Hong & Melville (2018), Degirmenci (2018) and Healy & Walshe (2020) all suggest that learning and applying GIS to the classroom requires adequate hands-on practice to allow teachers time to master the technology. Similarly, Lay (2013) found that Taiwanese Geography teachers' usage of GIS is affected by their peers and their schools. His statistical findings indicate that "perceived usefulness" of GIS and school support are important factors influencing teachers' adoption of GIS. His study used a sample size of over a thousand and it was fascinating to see how in-service GIS teacher training is conducted in Taiwan. Taiwan use FOSS4G and Google maps in the classroom and he found that free software was attractive because it reduces potential adopters' concerns about having to expend too much energy and resources in acquiring and applying GIS (Lay, 2013).

Collins and Mitchell (2019) recommend that to achieve long-term success with GIS implementation in the classroom, pre-service teacher training in Geography should improve to include adequate training in GIS, beyond merely the awareness of what GIS is. Their study is one of the few that looked at follow-up in-service training and coaching. It is unique in the literature in that they interviewed teachers after a year of training to determine if teachers were continuing to teach with GIS and if so, how. Digan (2019) agrees with Collin and Mitchell (2019) and adds that with the inclusion of GIS in the Australian Curriculum there is a need for specialised teacher training to make GIS integral in the secondary school environment. Both studies concur that the lack of teacher GIS knowledge, skills and experience limits the implementation of meaningful and authentic GIS projects in schools (Digan, 2019; Collins & Mitchell, 2019).

It was also suggested that to increase the GIS practices in Geography lessons, an important teacher intervention would be creating a platform where different GIS examples from all over the world are brought together for teachers to get acquainted with new trends in GIS pedagogy (Degirmenci, 2018; Digan, 2019). Studies involving scholars showed that using GIS in the classroom helps develop many geographic skills, in particular their map and questioning skills (Lateh & Muniandy, 2010; Aladag, 2014; Riihelä & Mäki, 2015; Degirmenci, 2018; Digan, 2019). Kerski *et al.* (2013) also recommended that any effort that builds the community of educators so that they will not feel alone and can partner with one another in planning and teaching lessons. Another compelling justification for incorporating GIS in education is a workplace skill for the geosciences industry and this may encourage teachers to adopt this technology in their lessons (Riihelä & Mäki, 2015).

2.6 Background to GIS in South Africa

The South African Department of Basic Education (DBE) listed GIS as a “skill to be acquired” in the National Curriculum Statement (NCS) for Geography in 2003 (DBE, 2018).although its actual inclusion in the curriculum was only phased in from 2006–2008. GIS was later revised in the Curriculum Assessment Policy Statements (CAPS) in 2013 for inclusion in the grade 10 to 12 Geography curriculum (Table 2-1)(DBE, 2018). A number of core GIS competencies were identified as essential for the geosciences industry (Du Plessis, 2012) and these were in turn condensed for the current Geography Curriculum Assessment Policy Statements (CAPS) taught in secondary schools in South Africa (DBE, 2018).

Table 2-1 GIS in grade 10 to 12 South African Geography Curriculum (CAPS) (DBE, 2018, page 16).

Grade 10	Grade 11	Grade 12
Geographical information systems (GIS) • Concept of GIS • Reasons for the development of GIS • Concept of remote sensing • How remote sensing works • GIS concepts: spatial objects, lines, points, nodes and scales	Geographical information systems (GIS) • Spatially referenced data • Spatial and spectral resolution • Different types of data: line, point, area and attribute • Raster and vector data • Application of GIS to all relevant topics in the grade • Capturing different types of data from existing maps, photographs, fieldwork or other records, on tracing paper	Geographical information systems (GIS) • GIS concepts: remote sensing, resolution • Spatial and attribute data; and vector and raster data • Data standardisation, data sharing and data security • Data manipulation: data integration, buffering, querying and statistical analysis • Application of GIS by government and the private sector • Relate to all topics in Grade 12 • Develop a “paper GIS” from existing maps, photographs or other records on layers of tracing paper

Three main impediments to the successful integration of GIS within schools that can be considered for GIS education in South Africa (Kidman, 2006). Namely, money (the introduction of computerised GIS in any schooling system requires considerable financial input in terms of purchasing the necessary software, hardware, and educational materials as well as money for the training of educators); Kidman (2006) outlined three levels of support required: first, support from school leadership and the school community; second, support from local tertiary institutions offering educator education programs; and third, support from government and industry); and time (they referred to the time required for educators to attend professional development workshops to learn the necessary GIS software; the time required to develop or modify instructional materials supported by GIS; as well as the time required in the curriculum of various subject disciplines to effectively educate learners about the technology (Kidman, 2006). Geography teachers from all nine provinces in South Africa indicated a shortfall of hardware, internet access, material and training (Fleischmann & van der Westhuizen, 2017). Mzuza & Van Der Westhuizen (2019) refer to the same challenges in their review, more than fifteen years after Kidman (2006). The main problems they identified were: shortage of experienced teachers; inadequate resources; the lack of knowledge and the unwillingness of teachers to change their method of teaching (Mzuza & Van Der Westhuizen, 2019).

Although GIS has been included in the South African curriculum over the past decade, the majority of teachers continue to lack formal GIS training, resources, and support (Fleischmann, 2017). Both international and local studies conclude that the lack of GIS training of teachers hindered the effectiveness of GIS interventions in the classroom (Scheepers, 2009; Milson *et al*., 2012; Komlenović *et al*., 2013; Artvinli & Martinha, 2014). The study conducted by Fleischmann *et al*. (2015) presented a potential solution to this problem: A multimedia set of lessons referred to as an Interactive-GIS-Tutor (IGIST) that offers teachers the option of using either a computer connected to a digital projector or a computer laboratory within the same application (Fleischmann & van der Westhuizen, 2015). Both Fleischmann's (2015) and Ciolli's (2017) study used the FOSS4G software QGIS. Fleischmann *et al*. (2015) set up a series of exercises and tutorials (packaged as IGIST). The author felt that IGIST not only enhanced the learners' GIS understanding, but also their own understanding. Similar studies where a GIS tutorial was created concluded that there must be a balance of teacher motivation, curriculum time constraints and teacher support to make this an effective teacher intervention (Fleischmann & van der Westhuizen, 2015; Riihelä & Mäki, 2015; Degirmenci, 2018).

In Milson *et al.*'s (2012) study, South Africa was one of only eight countries where GIS forms part of the formal national secondary school curriculum. The others are China, Taiwan, Turkey, United Kingdom, Finland, India and Norway (Milson *et al*., 2012). A number of providers have developed teacher and learner resources for South Africa in the last ten years. Examples include ESRI's Funda Lula, which uses multi-media videos, teacher and learner notes and digital presentations (ESRI SA); Macmillan's Secondary Map Skills textbook that includes a disk with QGIS and local data sets (Fleming *et al*., 2014); Geomatica was TNTmips-based software developed into interactive GIS lessons and later incorporated into Maptrix (Innes, 2009); Pearson's Interactive Atlas which is based on an interactive multimedia platform; AfriSpatial's school GIS data packs (Fleming, 2013) and IGIST, an 'Interactive-GIS-Tutor' which is a multimedia teaching tool (Fleischmann & van der Westhuizen, 2015). Various videos on the theme 'Gentle introduction to GIS' produced in 2010 by Linfiniti and funded by the Chief Directorate: Spatial Planning and Information, DLA (Department of Land Affairs) of the Eastern Cape Province are available online, providing mini-lectures on how to use QGIS (Fleischmann & van der Westhuizen, 2015).

The question of whether GIS could be successfully taught in resource-poor schools in developing countries such as South Africa where technological and bureaucratic barriers so frequently impede the learning process was the main focus of this study (Breetzke *et al*., 2011). This research was based on evaluating a paper-based GIS package in under-resourced schools developed and distributed by ESRI South Africa. In another study of three different categories of schools in the country: private, public, and previously disadvantaged, they concluded that the lack of appropriate curriculum guidelines, teaching resources, and instructional manuals has further hindered its introduction, particularly into resource-poor schools in the country (Eksteen *et al.,* 2012). As a result, private companies such as ESRI South Africa, Intergraph, and Naperian Technologies developed educational material and conducted a number of GIS in-service training courses aimed at teaching curriculum advisors and teachers (Eksteen *et al*. 2012).

NGI (National Geospatial Information) is one of the custodians of spatial data in South Africa. Although data sets from NGI are free and readily available, they remain inaccessible to teachers who are often overwhelmed with different data formats and the large size of data (Fleming, 2013). A key element of effective implementation of GIS at secondary schools is teachers' positive attitude towards GIS (Demirci, 2009; Millsaps & Harrington Jr, 2017; Degirmenci, 2018).

Mzuza (2019) is one of the only studies that refers to QGIS use in Southern African classrooms and that it was thanks to the great strides in free software that it is now commonly used and generally available. However, the study refers to how it can only be used when connected to the internet which is not the case with QGIS, since once it is downloaded, the user does not need connectivity. This study also concluded that the four countries in southern Africa that teach GIS as part of the curriculum (South Africa, Lesotho, Malawi and Botswana), many of their schools only offer the theoretical rather than the practical (hands-on) teaching of GIS. The study attributes this to teachers not having the knowhow to present the GIS content together with the lack of hardware and connectivity (Mzuza & Van Der Westhuizen, 2019). Other researchers attribute financial constraints as the major cause of many schools in Africa not having enough computers for teaching and learning purposes (Breetzke *et al*., 2011; Bearman *et al*., 2016).

2.7 Teacher interventions for GIS in South Africa

Historically in South Africa, many researchers concur that the lack of GIS teacher training is deleterious to how effectively GIS is taught in the classroom (Scheepers, 2009; Innes, 2009; Breetzke *et al*., 2011; Eksteen *et al*., 2012). Eksteen *et al*. (2012) concludes that the final challenge to the successful infusion of GIS into secondary schools throughout the South Africa is adequate and continuous administrative and technological support. Ideally, three levels of support are required:

- support from school leadership and the school community;
- support from local tertiary institutions offering teacher education programs
- support from government and industry

ESRI SA, GISSA (GIS Society of South Africa), a university (University of Johannesburg) and the private sector (MacMillian Teacher School with AfriSpatial) have offered short GIS courses for teachers. Zondi *et al*. (2020) recently concluded that GIS was not properly taught at the schools that participated in her study in KwaZulu-Natal province in South Africa. This study concluded that there was a lack of fundamental knowledge of GIS amongst the grade 12 learners who participated in the study (Zondi & Tarisayi, 2020). Wilmot and Dube (2016) state that there is a need for empirical studies for the understanding the state of school Geography from the perspective of teachers. The review of literature in South Africa also mentions the fact that there is also a need to address the fundamental problem of inequalities such as GIS-enabling resources in Geography education in South Africa (Wilmot & Dube, 2016; Fleischmann, 2017; Mzuza & Van Der Westhuizen, 2019; Zondi & Tarisayi, 2020).

Furthermore, there is unambiguous agreement amongst current global studies that more research into inequalities of GIS teaching is required (Hong & Melville, 2018; Collins & Mitchell, 2019; Healy & Walshe, 2019). Teaching with GIS needs to include knowledge, skills and behaviour. It is up to those who believe in the power of spatial analysis through GIS to take active steps to ensure that educational transformation happens for the sake of the planet and society (Kerski *et al*. 2012). Fleischmann *et al*. (2015) and Mzuza *et al*. (2019) were the only publications in this review that looked at FOSS4G software in a local context and no study reviewed locally or globally, used OSM as a data source in their research.

Chapter 3 Methodology

3.1 Why the mixed methods approach was adopted

The use of a mixed methods approach is well-established in this type of study, where the advantages of using both a quantitative and qualitative methodology can be utilised. Namely, the results of the survey can be graphed and analysed, and interview transcripts can be coded thematically and discussed. The strategy used in this research for mixed methods was based on Creswell's (2009) sequential quantitative approach. This was chosen as the first part of the research allowed a quantitative approach with the use of an online survey as a research tool. The researcher embedded a qualitative approach by including the use of interviews to get a better understanding of the quantitative data. Furthermore, a mixed method approach was employed since the research required one to build on the results obtained from the quantitative survey results by interviewing a smaller sample of teachers (n=9).

The first aim was to determine the status of the teaching of GIS in secondary schools in South Africa with respect to teacher skills and resources available. This allowed for a qualitative approach as Part A of the survey instrument (online questionnaire) asked questions to determine GIS skills and GIS resources accessible to teachers. Part B of the survey instrument used a quantitative approach and looked at the different types of GIS resources that were available to teachers. Part C of the survey instrument was a teacher reflection on the use of GIS in the classroom (Appendix C). The answers from Parts B and C of the survey for the qualitative research were cross-tabulated and interpreted.

The teachers interviewed for the qualitative research were first shown a demonstration of how OpenStreetMap (OSM) data could be used to capture and digitise local spatial data of their schools or communities. Then they were shown how QGIS software could be downloaded and used to produce maps for local research projects. The excitement about GIS's potential that Collins and Mitchell (2019) discusses once teachers were shown this demonstration was palpable. Step by step instructions on how use OSM and QGIS was designed by the researcher as worksheets for grade 10 to 12 learners. These worksheets on how to use OSM data and QGIS (Appendix E) and was then shared with the participants after the interviews as a teaching resource. An evaluation of the students pre- and post-performance using OSM and QGIS is a possible area for future research.

Interviews took place between 22 October 2019 to 6 March 2020. It was fortuitous that the last interview took place the weekend before COVID 19 lock down restrictions were implemented so none had to be conducted online. All nine interviews were conducted in person.

3.2 Ethical considerations

Respondents who completed the online survey were informed that participation was voluntary, and they did not receive any benefit from participating nor any penalties for not participating. Completing the survey did not require the respondents to answer all the questions and that is why the answers range from 103 to 112 responses to the 30 questions asked and only 63 gave reflective answers to the one open ended question. Prior to undertaking the investigation, ethical clearance was obtained from Wits University Ethics Committee. Participants were assured that the surveys were anonymous and no email address or name was linked to any of the answers in the survey.

The researcher interviewed only teachers from Independent schools in adherence to Ethics stipulations. There was one exception, however: the second interviewee had recently taught in a government rural school and volunteered some of his insights from teaching there, which I have included in the results with his permission. He was no longer employed in a government school.

3.3 Quantitative data collection

The design of the questionnaire was based on Creswell's (2009) criteria for what a survey instrument should cover. The researcher developed the instrument after reviewing questions from previous studies (Breetzke*et al*., 2011; Demirci, 2011; Hong & Melville, 2018; Collins & Mitchell, 2019). The online survey link was posted on the Southern African Geography Teachers' Network mailing list and participants were invited to complete the survey (Southern African Geography Teachers Network, 2019). A Google Form (Appendix C) was used, and results were analysed in Excel. One hundred and twelve participants took part in the survey.

Two types of scales were used in the questionnaire, namely the continuous scale (strongly agree to strongly disagree) using the Likert scale and the categorical scale (rank highest to lowest) (Creswell, 2009). Part A of the survey instrument also asked questions to ascertain the demographics and location of the respondents. This was important to determine if the sample for the study involved stratification of the population (Creswell, 2009) and to determine if the sample had national coverage. The type of school (urban or rural), how well resourced the school is, the Examination Board that the curriculum teaches to and how many teachers teach Geography at the school (to determine the size of the Geography Department).

The next set of questions determined the years of teaching experience and how much GIS expertise and training the respondents had. The questions then determined which part of the Geography curriculum GIS was taught in each grade group and if a practical component was taught, or only the theory. The last questions asked participants to reflect on their teaching practice and how GIS could be utilised in the classroom. The research questions were categorised into variables and the links to the survey questions were summarised in Table 3-1.

Table 3-1 Research themes, research questions and items on the survey instrument.

Research Theme	Research Question	Item on the Survey Instrument/ Online Questionnaire (see Appendix C)
To establish the demographics of the participants.	Descriptive research question: Age, gender, teaching experience, location, Examination Board	Question 3, 4, 7, 8, 9.
The type of school the participant teaches in and how many resources available to teach GIS.	Descriptive research question: Description of school, rural/urban, government, private, size of the Geography Department, hardware and software available, Wi-Fi connectivity, accessibly of ICT	**Question 1, 2, 5, 19, 21, 22, 23, 24, 25.**
How GIS is taught in the classroom.	Descriptive research question: number of pupils who take Geography, when GIS curriculum concepts are taught and how	Question 6, 13, 14, 15, 16, 18, 20.
The level of GIS experience and skills.	Descriptive research question: GIS expertise, GIS courses attended, frequency of IT use, techniques used, practical GIS, when GIS is used to help teach the curriculum, level of interest in GIS, knowledge of OSM, interest in attending future GIS courses, applications, reflections	Question 10, 11, 12, 17, 26, 27, 28, 29, 30.

The survey sample of 112 could be divided equally into two groups, namely those who teach to the DBE (50%) and those who teach to the IEB (49%) examination. One percent of the sample teach Cambridge or other. Cross-tabulating the data in Excel pivot tables allowed for some connections to be made. Microsoft Excel and Google Sheets were used to tabulate and graph data. QGIS was used to present data that had a location attribute and was used to produce all maps.

3.4 Qualitative data collection and verification

The second aim of the research involved an evaluation of whether FOSS4G, namely open-source software (QGIS) and open data (OSM) would be effective teacher interventions in South African schools. Parts B and C in the survey were designed to determine the extent of FOSS4G data and software use in secondary schools and teachers' awareness of these resources. The study then used qualitative analysis to gain insights into the extent of teachers' understanding by interviewing a sample of teachers of varying ages, years of teaching experience and gender. According to Merriam & Tisdell (2016; 23), qualitative research is based on the belief that knowledge is constructed by people in an ongoing fashion as they engage in and make meaning of an activity, experience, or phenomenon. The activity presented to the participants was a demonstration of a FOSS4G lesson that could be used in the classroom.

Merriam & Tisdell (2016) identifies several advantages of using a basic qualitative approach of the five approaches she mentions. The most common form has as its goal understanding how people make sense of their experiences. Data are collected through interviews and observations and are analysed inductively to address the research question posed (Merriam & Tisdell, 2016).

Interviews were conducted in person at the schools and teachers were sent the interview questions (Appendix D) in advance to allow them time to reflect on their answers. Questions for the interviews were designed to evaluate teacher perceptions and were based on Tabor & Harrington (2014) and Komlenovic's (2013) studies. Because these studies were a few years old and the software (QGIS) had gone through many updates, the questions asked were adapted to include the recent OSM plugin for the QGIS software.

Semi-structured interviews with the teachers took place with teachers individually and were then used as a means to further clarify and explain the results obtained through the quantitative survey. The interview process started with a ten-minute demonstration of how OSM data and QGIS could be used in a lesson. The interviewees were firstly shown how to register on OSM; how to find their school (location of their choice); how to digitise and edit vector data; how to add attribute data and then how to export their data. This was then followed by a short demonstration of how QGIS could be used to load the OSM data as a vector layer; how to style the data and how to produce a map (Appendix E). This was done individually and not as a focus group, as a disadvantage of conducting the interviews in a group is that the interviewee's answers could be influenced by others. Creswell's (2009; 183) interview protocol was followed which included the following:

- Place, date and time, interviewee.
- The questions (Appendix D).
- Probes to follow up and to ask participants to explain their ideas in more detail.
- Thank you statement.

The data was recorded on a digital audio recorder and transcribed by the researcher. Once the themes had been coded thematically, the researcher checked with the participant interviewed to see if they agreed with the findings. The process of data validation followed Creswell's (2009) method of data analysis in qualitative research as illustrated in Figure 3-1 (adapted from Creswell, 2009).

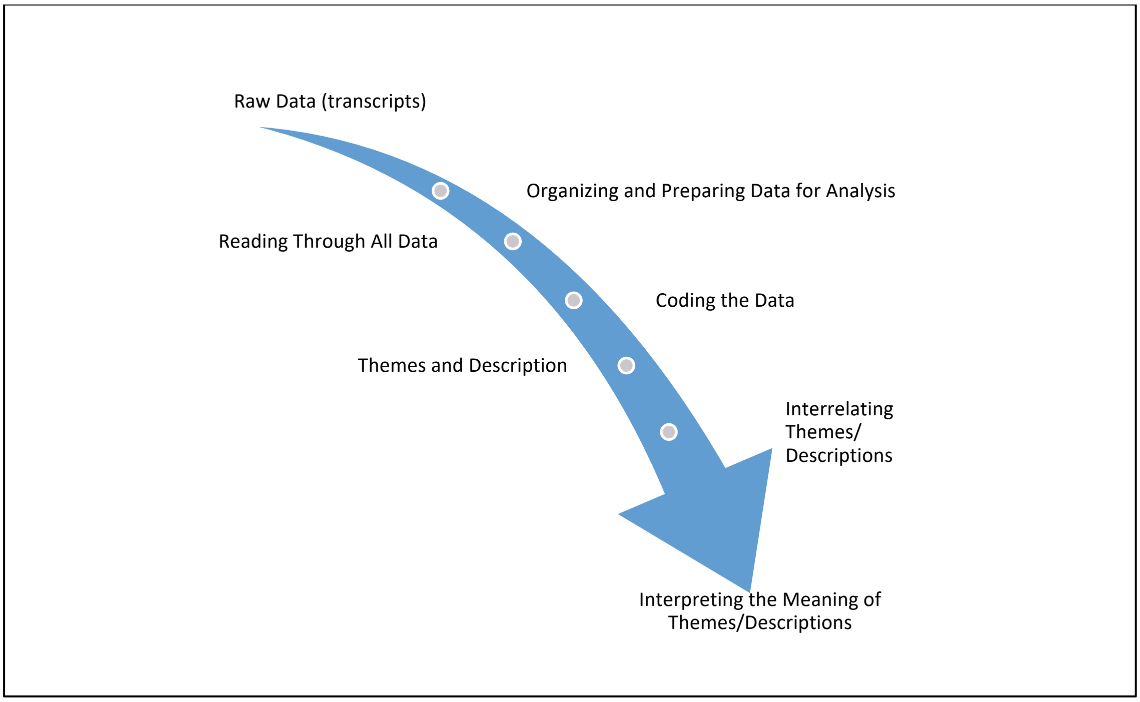


Figure 3-1: Schematic of validating the accuracy of the information (adapted from Creswell, 2009).

The criteria for selecting the participants to be interviewed were as follows:

- Location (provincially and urban and rural situations)
- Years of teaching experience ('new teacher' to 'retired teacher')
- Interest in using GIS in the classroom ('none' to 'extensive')
- Type of school ('monastic' or 'co-educational')
- Examination Board (DBE or IEB and other)
- They all expressed a willingness to test these new GIS interventions

The sample of nine teachers interviewed came from four provinces around South Africa (Gauteng, W Cape, E Cape and KZN) to ensure some national coverage and to avoid location bias. Data was generated using semi-structured interviews allowing flexibility to probe for clarity (Creswell, 2009). The recorded interviews were transcribed and the identified themes tabulated and discussed.

Chapter 4 Results

A mixed methods approach was used and the data for the quantitative and qualitative research was collected concurrently. The survey instrument (Appendix C) used for the quantitative approach was designed using two types of scales, namely the Likert scale and the categorical scale (Creswell, 2009) and set up in three parts, namely Part A, B and C. The quantitative results for Part A of the survey show stratification of the population by age, gender, years of teaching experience, qualifications, which Examination Board they teach to and their location (to show national coverage). These results establish the demographics of the respondents. Part B of the survey instrument looked at the type of school, hardware and software, Wi-Fi connectivity, GIS resource type and accessibility to teachers. Part C of the survey instrument was a teacher reflection on the use of GIS in the classroom to ascertain how GIS is taught in the classroom and the level of GIS experience and skill set of the teacher.

Semi-structured interviews took place with nine participants who were identified by their willingness to participate and for representing a sample group of the predicted demographics results for the online survey (age, years of teaching experience, type of school, location of school and Examination Board). This was done to ensure validity when results for the quantitative and qualitative data were compared. The participants' answers to the interview questions were recorded, transcribed and coded manually under identified themes to further clarify and explain the results obtained through the quantitative survey in Part B and C.

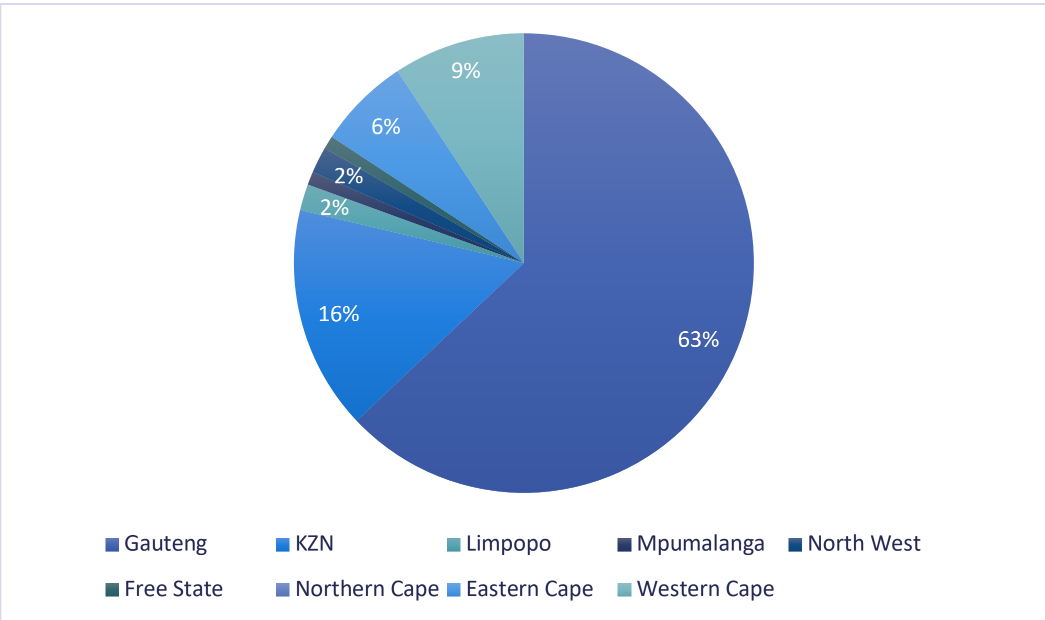
4.1 Results from the online survey

A total of 112 respondents completed the online survey during November 2019 to February 2020. The numbers of responses for each question ranges from 103 to 112, with the exception of the open-ended reflective question where only 63 respondents elected to type in their answers. The online survey questions can be found in Appendix C and the results will be presented in research themes rather than in the order that the questions were asked.

4.1.1 Demographics of the participants

The majority of participants are from schools located in Gauteng (63%), followed by KwaZulu-Natal (16%), Western Cape (9%), Eastern Cape (6%), Limpopo (2%), North West (2%), Mpumalanga (1%) and Free State (1%) and none from the Northern Cape as can be seen in Figure 4-1 (a) and (b).

(a)



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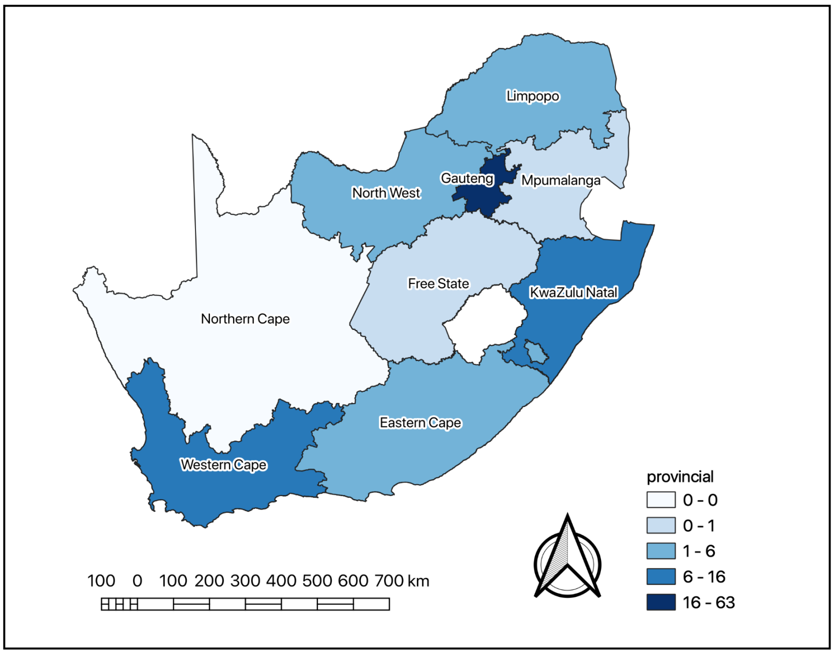

Figure 4-1: (a) Percentage of respondents from each province (n=108) and (b) Map showing the distribution of respondents by percentage across South Africa (produced with QGIS).

There was an almost equal number of the respondents who follow either the Independent Examination Board (49%; 55 of 112) or the Department of Basic Education (50%; 56 of 112) examinations (Figure 4-2). The sum of the total number of responses equates to 114 and this is due to two respondents teaching to both IEB and Cambridge curricula.

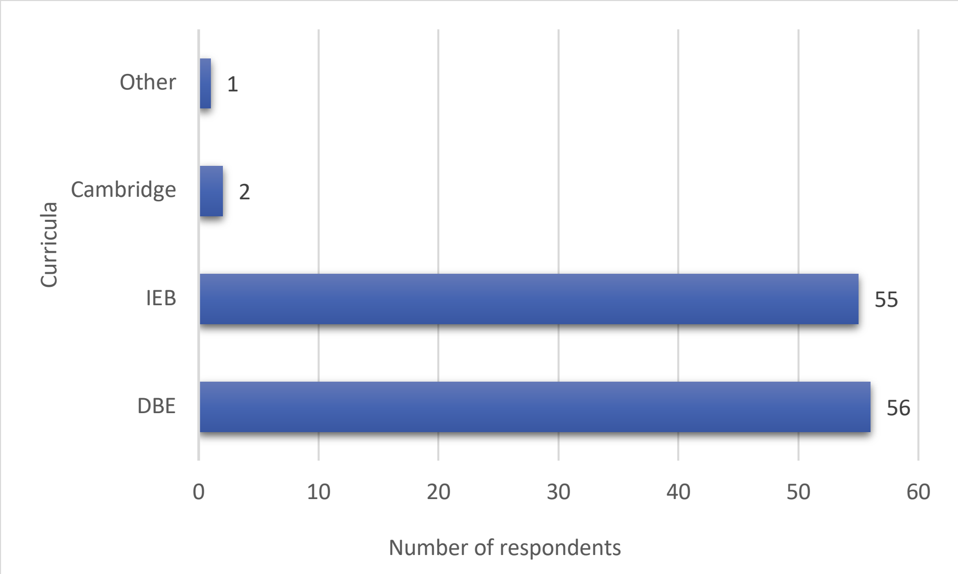

Figure 4-2: Number of respondents who teach to the different curricula/ Examination Boards (n=114).

The greatest number of respondents are females (62%) whereas males make up 36% (Figure 4-3). Of the 112 respondents, two percent preferred not to disclose a gender.

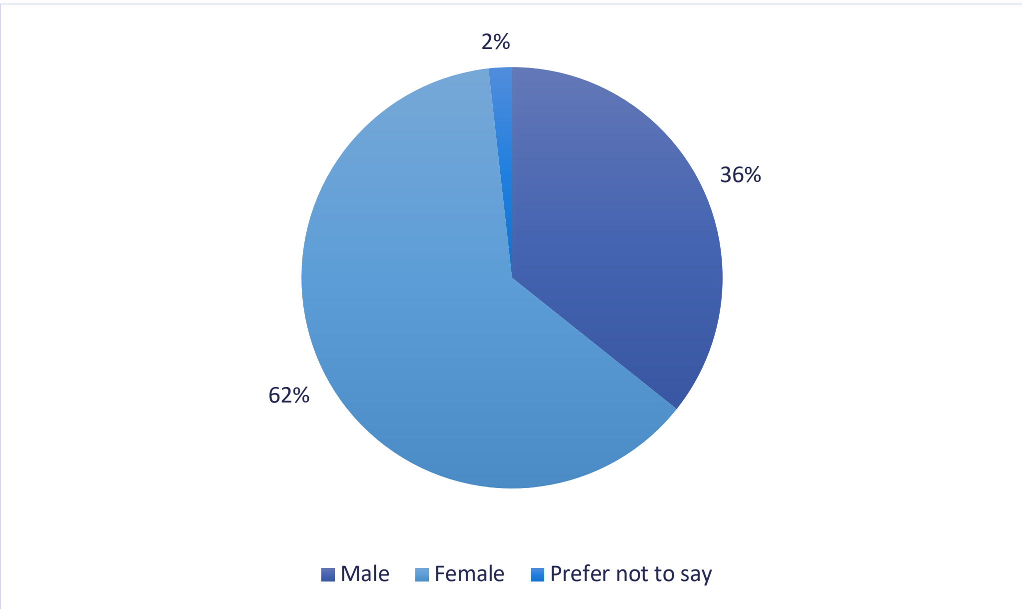

Figure 4-3: Gender distribution of participants (n=112).

The age distribution of the participants is 40 to 49 years (30.4%; 34 of 112), followed by 50 – 59 years (25%; 28 of 112), 30 -39 years (17%; 19 of 112) and 20 to 29 years (13.4%; 15 of 112). The rest (13.3%; 15 of 112) fall into the 60 plus age group (Figure 4-5).

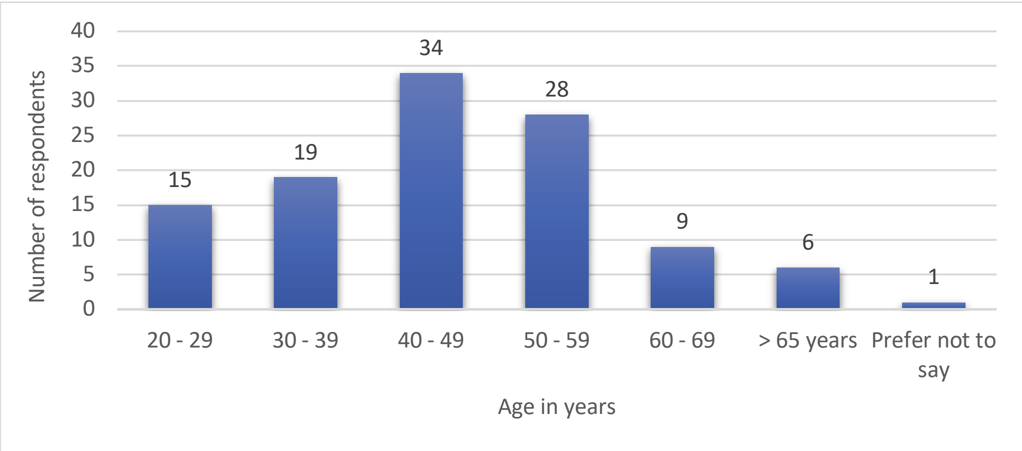

Figure 4-4: Age distribution of participants (n=112).

The majority of respondents have taught Geography at secondary level for either under five years (24.1%; 27 of 112), between 21 and 30 years (25%; 28 of 112) or over 31 years (21.4%; 24 of 112) (Figure 4-5). This is significant as these results show that 52% of respondents have substantial teaching experience (over 20 years). However, a quarter of the respondents have less than five years' experience, so, a wide range of expertise is represented in the data (Figure 4-5).

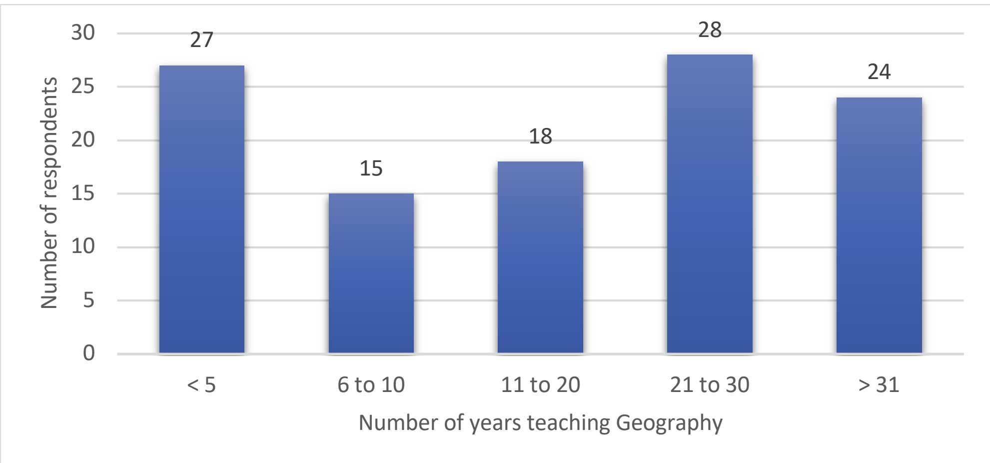

Figure 4-5: Number of years of teaching Geography at secondary school (n=112).

4.1.2 The type of school the participants teach in and the GIS-enabling resources available

The descriptive survey research questions in this section deal with how resourced the schools are, whether rural or urban, government or private, the size of the Geography Department, the hardware and software available, Wi-Fi connectivity and the accessibly of ICT.

Most of the respondents (56%; 63 of 111) believe the school they teach in to be well to very well resourced (Figure 4-6). Twenty five percent (28 of 111) believe their school to be under resourced or missing resources as that may influence why practical GIS lessons are not being taught.

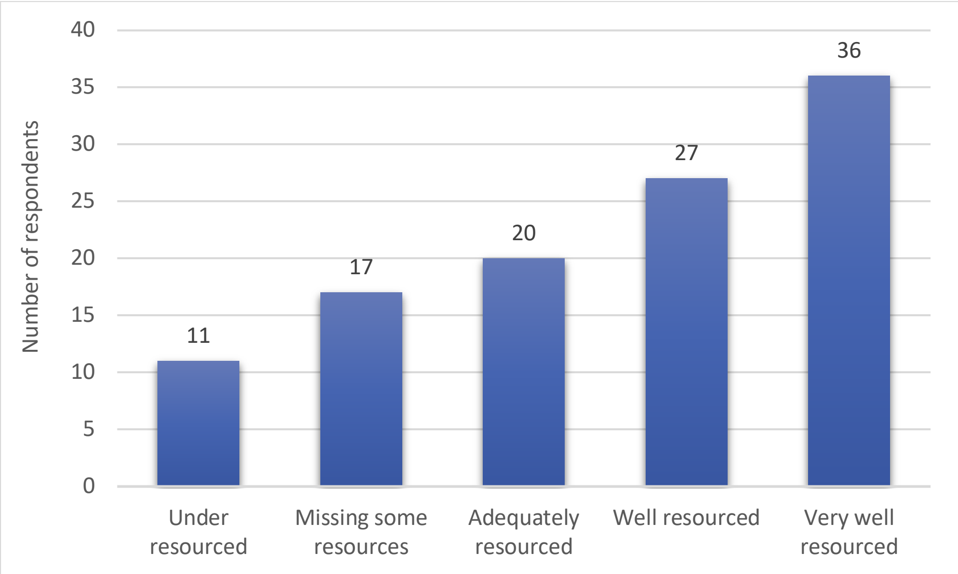

Figure 4-6: How resourced the participants see the school that they teach in (n=111).

A total of 56% (64 of 113) of the respondents teach in private schools and 44% (49 of 113) teach in the government sector. Of those teaching in the private sector, the majority teach in urban schools (94%; 60 of 64), compared to the government sector, in which 75% (37 of 49) teach in an urban environment. Only 14% (16 of 113) of participants service a rural community (Figure 4-7).

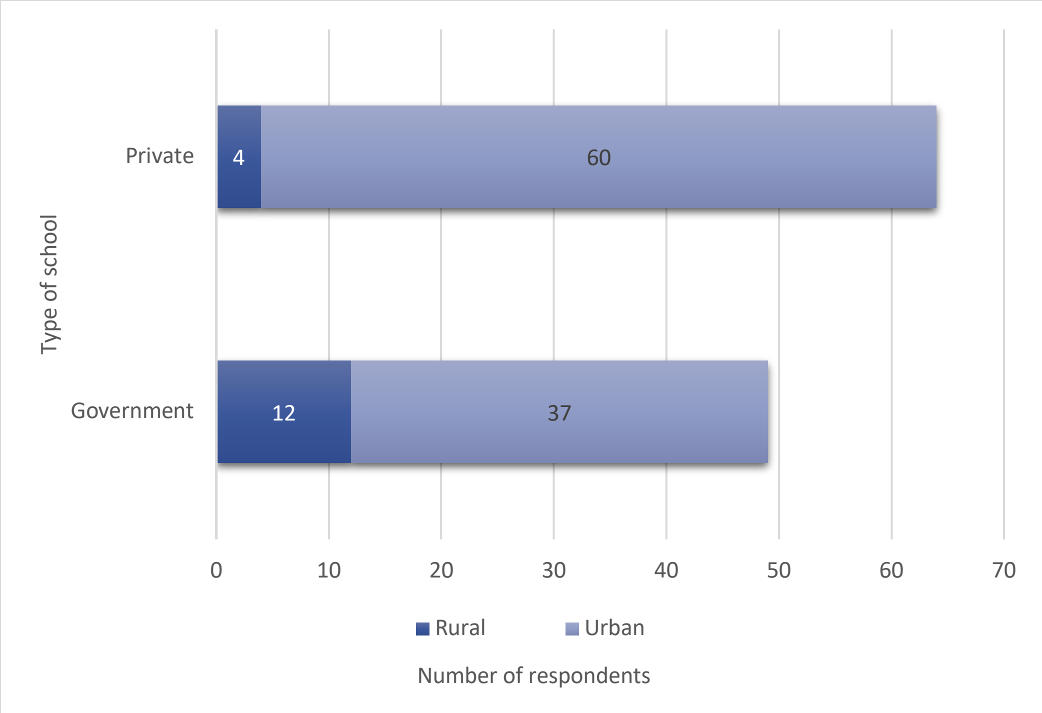

Figure 4-7: The number of participants who teach at government vs private schools (n=113).

The majority of schools represented in this survey have two Geography teachers (37%; 41 of 110). Twenty four percent (26 of 110) have three Geography teachers, 19% (21 of 110) have one Geography teacher, 11% (12 of 110) have four Geography teachers and 9% (10 of 110) of the schools have five or more Geography teachers in their Department (Figure 4-8).

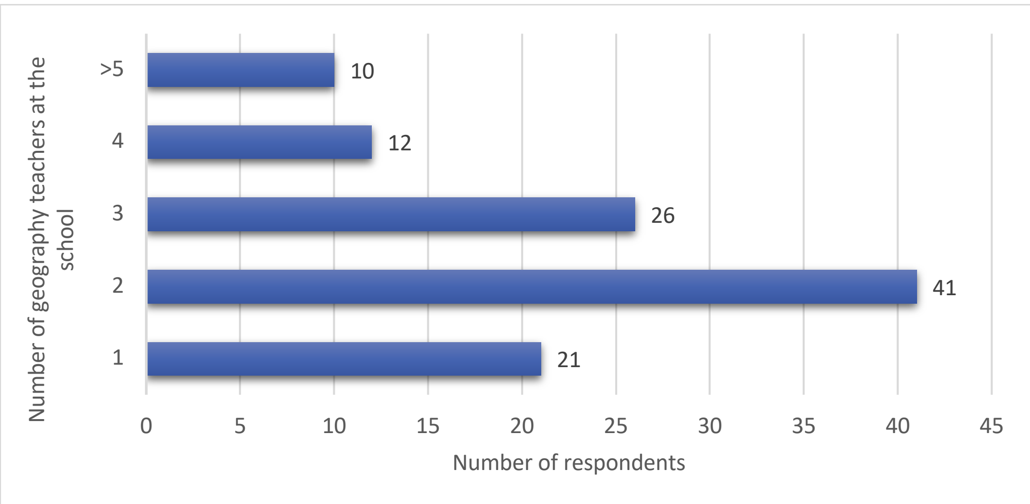

Figure 4-8: Number of teachers that teach Geography at the participants' school (n=110).

Only 4.5% (5 of 112) of participants do not have the use of a computer in the Geography classroom. Seventy eight percent (87 of 112) of participants have their own laptop and furthermore 22.3% (25 of 112) have the use of the IT lab and computer room (Figure 4-9).

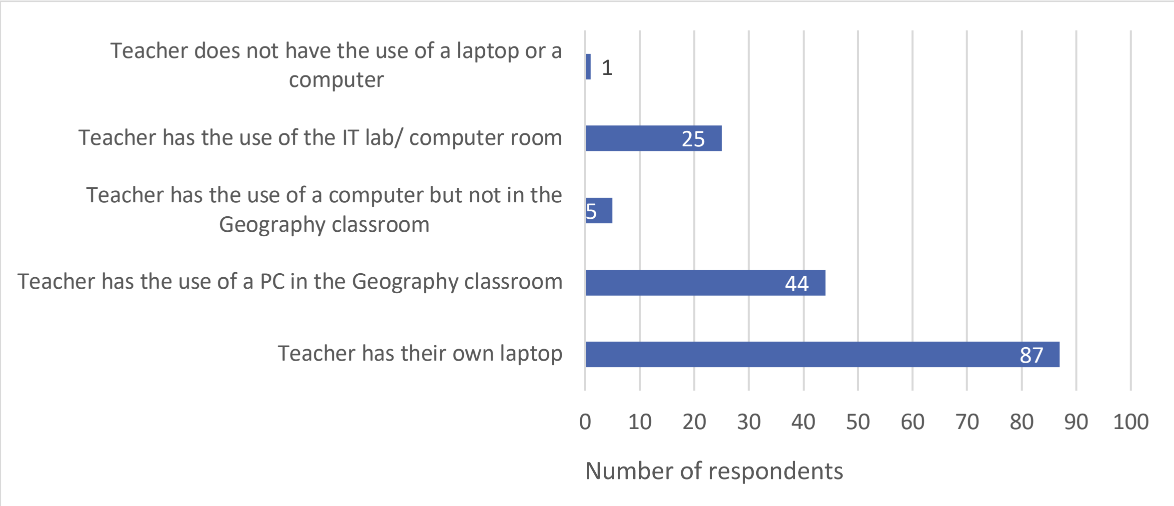

Figure 4-9: Computer hardware available to the teacher (n=112).

The two most sought-after GIS-enabling resources that participants would like to have access to in the classroom are GIS courses and practical lessons and GIS data, 79% (86 of 109) and 75% (82 of 109) of the participants respectively. This is followed by GIS software (63%; 69 of 109), GIS notes and lessons (59%; 64 of 109) and the least item identified is hardware (35%; 38 of 109) (Figure 4-10).

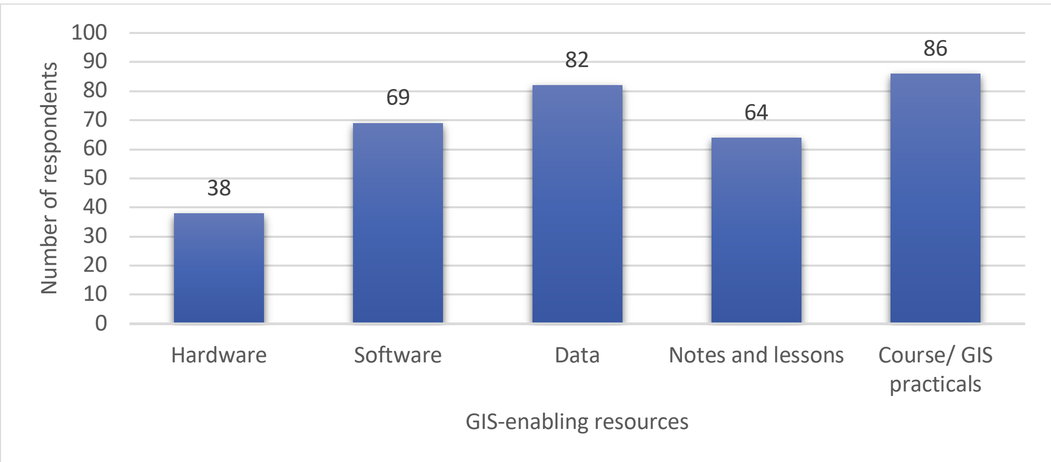

Figure 4-10: What GIS-enabling resources the teacher would like access to in the classroom (n=109).

Only 56% (63 of 112) of the respondents answered the open-ended question as the participants were required to type in what GIS-enabling resources they would like to have provided. The participants' answers are summarised in Table 4-1 and their responses are categorised under common themes that emerged. The most common GIS-enabling resources that participants asked for were practical lessons and activities for their students (41%; 26 of 63). The next most commonly requested resource was GIS software (19%; 12 of 63) followed by requests for GIS data (16%; 10 of 63). Only two participants requested hardware.

Table 4-1: GIS-enabling resources the teacher would like to have developed tabulated according to the number of respondents. Sub totals have been given in each category (n=63).

Respondents' answers	Number of respondents n=63	
Software:		
- We have Funda Lula but no time. We also have Arcview 3.3 and do some practical work.	1	
- Easy to use, no frills GIS software that does not hog bandwidth, with South African data sources.	2	
- Software that is easy for children to use and code to specific things - for example: code a map using GIS data to indicate ocean currents	2	
- Access to Funda Lula	1	
- Story maps	1	
- Software e.g. QGIS	1	
- A teacher friendly software that is consistently used across the board whereby teachers can show step by step what GIS involves and the importance thereof.	1	
- Open source with support	1	
- Latest info on QGIS	1	
- The software and GIS app	1	**12**
Hardware:		
- Digital resources e.g. computers	2	**2**
Practical lessons/ courses:		
- Easy activities for use on phones	1	
- Practical case studies/ GIS examples	8	
- Simple practical lessons/ activities/ lesson plans	8	
- I would like someone who is better than I am to teach my Grade 11s how to use it.	1	
- Simple GIS programmes that the students can practise on, to see layers, and data tables and rendering of the whole system together	1	
- Student orientated short course that can be taught by the teacher	1	
- Simplified GIS programmes	1	
- practical lessons for learners be it paper GIS or computer based	1	
- Courses/ Workshops on Teaching GIS	1	
- Student examples of best practice from ORT or research projects	1	
- Step-by-step guides for software	1	
- Online courses for teachers, online 'help line' for teachers.	1	**26**
Notes:		
- Step-by-step for dummies notes (with pictures) to explain how to use GIS in a practical lesson	2	
- Standardised GIS notes	1	**3**
Data:		
- Data to enable students to learn as they do the work. Not book work but real experience the power of GIS	1	
- GIS data	3	
- Original 1:50 000 topographic maps in vector format	4	

- Sharing platform for GIS data. - Map downloads	1 1	 10
Other: - Resources suitable for beginners at grass root level - Easy and practical resources that are easy to access. - Maps, PowerPoint presentations, topographic vectors, Wi-Fi - Concise outlines of what syllabus expects - Not sure at this stage - Content videos, PowerPoint slides as well as have demonstrations of GIS software - Laboratory conversion from CAT to GIS - Time ☺ - Integration of topography to DEM	 1 2 1 1 1 1 1 1 1	 10
Total		63

The majority of participants (56%; 63 of 112) indicated that they have access to fast enough, high speed broadband connectivity. Twenty one percent (23 of 112) of the participants rate their connectivity connection as average. Ten percent (11 of 112) have some Wi-Fi connectivity and 13.4% (15 of 112) of teachers have no Wi-Fi access (Figure 4-11).

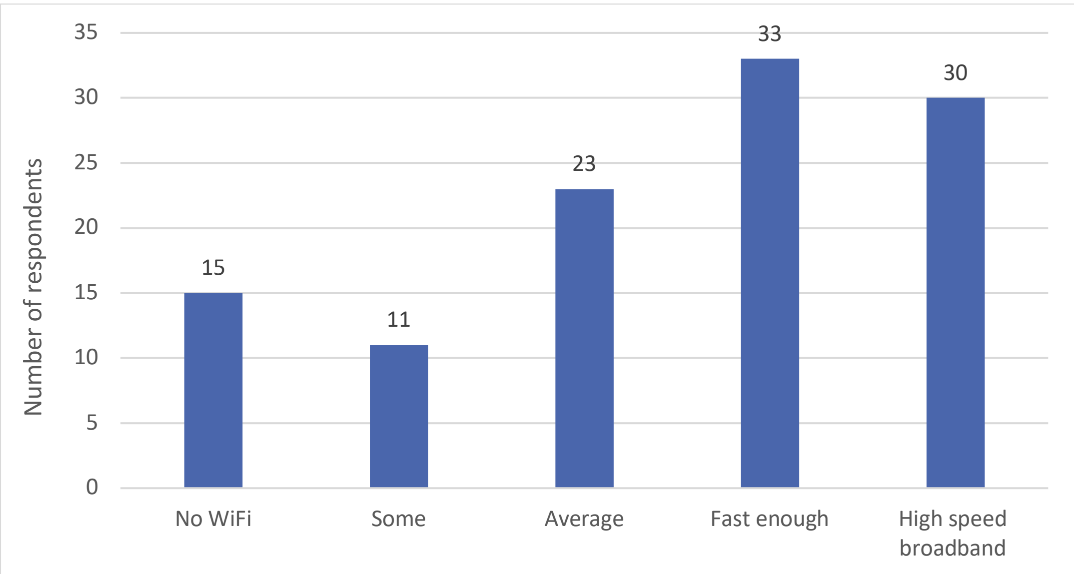

Figure 4-11: Level of Wi-Fi connectivity at the participant's school (n=112).

It is apparent from these results that the IT lab is not always available to use for Geography lessons (Figure 4-12). Thirty three percent (33 of 106) of participants said that it is difficult to book a time slot for a Geography class and 17% (18 of 106) said that they can never get to use it. Only 16% (17 of 106) said that the computer lab is always available for use for Geography lessons. The fact that 34% (36 of 106) said that they do not rely on the use of the IT lab is ambiguous. It may mean that the Geography Department has access to their own devices or that the teacher is not using IT in the Geography classroom. This is a limiting factor, which this researcher only realised after the questionnaire was sent out. Fortunately, data from later questions which asked the respondents how GIS can be made more accessible in the classroom clarified this (Figure 4-13).

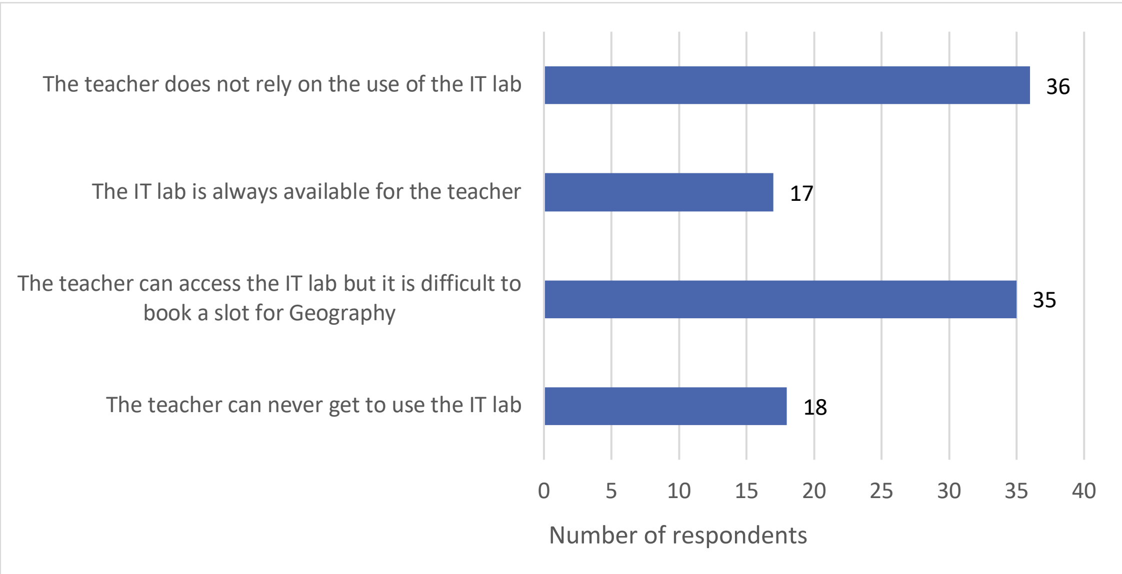

Figure 4-12: Assuming that the school has an IT lab, how accessible is the school IT lab for the Geography class (n=106).

The factor that the majority of the participants identified would help them to make GIS more accessible in the Geography classroom is pre-designed GIS lessons (66%; 73 of 111). This was followed by GIS training (61%; 68 of 111), access to local GIS data (54%; 60 of 111) and cheaper or free GIS software (50%; 56 of 111). Forty one percent (47 of 111) of the participants identified better access to hardware and Wi-Fi (Figure 4-13).

Similar questions were asked in Figure 4-9, Figure 4-10, Table 4-1 and Figure 4-12 and the question asking what would make GIS more accessible in the Geography classroom (Figure 4-13) was designed to ascertain exactly how GIS can be made more accessible by reinforcing concepts asked in the previously mentioned survey questions. This is important to evaluate the effectiveness of QGIS and OSM data as teacher interventions, a core part of this research.

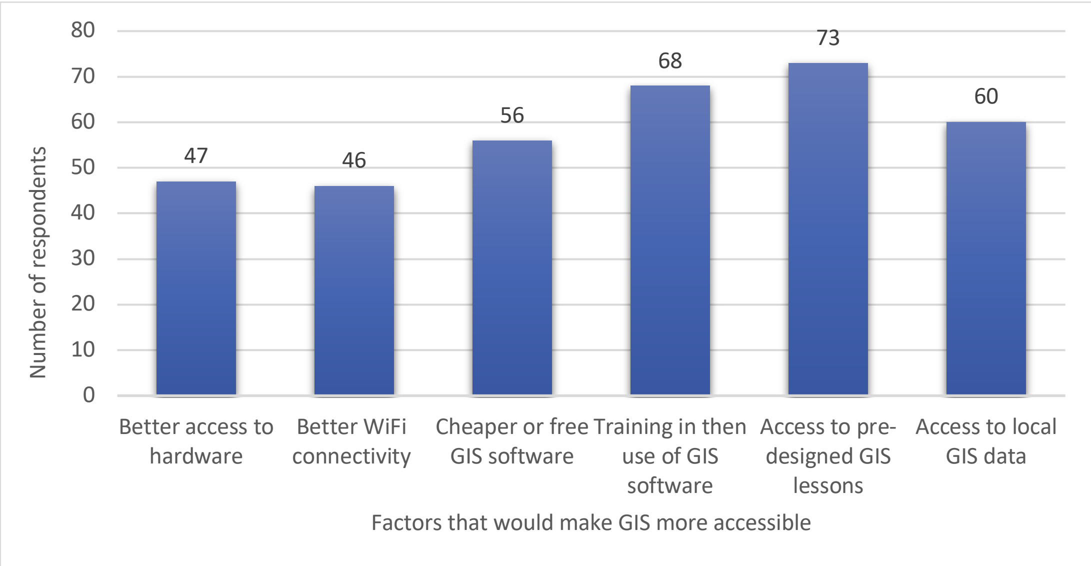

Figure 4-13: Factors that would make GIS more accessible in the Geography classroom (n=111).

4.1.3 How GIS is taught in the classroom

The descriptive survey research questions in this section deal with the number of pupils who take Geography to gauge the popularity of the subject; when GIS curriculum concepts are taught at secondary level; how they are taught and how often; what software and resources are used to teach GIS and the level of interest.

For grade 10, 11 and 12, the majority of schools that respondents teach at show that 21-40% of students take Geography as a subject at FET phase (Figure 4-14). For grade 12s the next cluster is 41-60% but what is concerning for the popularity of the subject is that this declines as the next peak in results in grade 10 and 11 is at fewer than 20% of students taking Geography. Only 13% (15 of 112) of respondents have 61-80% electing to take the subject and only 3 participants have the anomaly of more than 80% of student taking Geography as a subject.

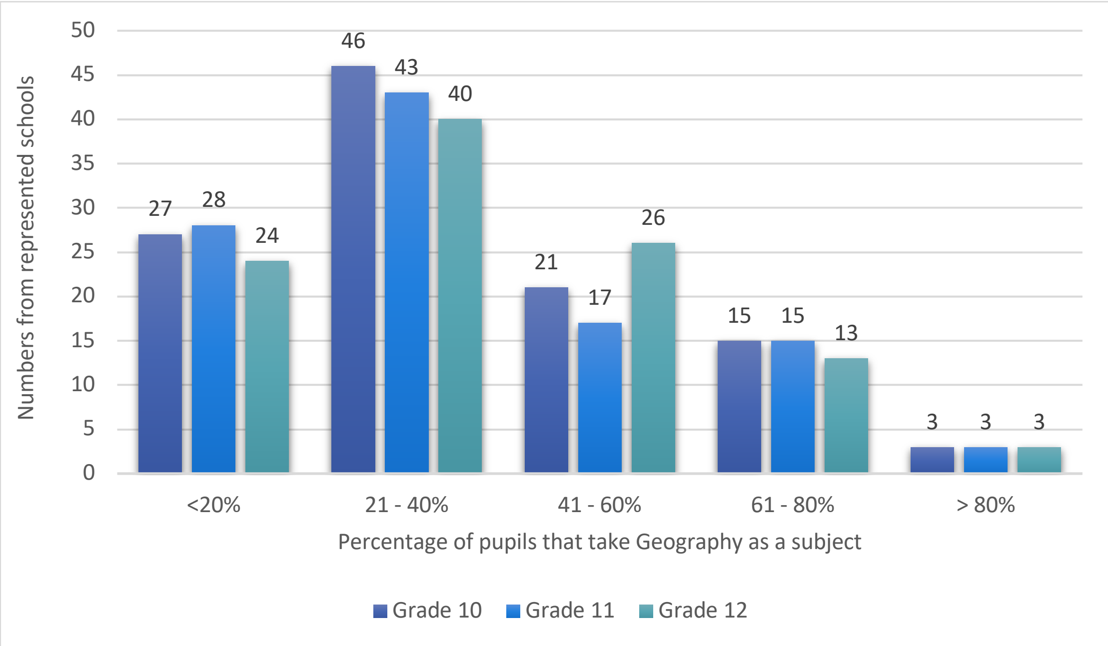

Figure 4-14: The percentage of pupils that take Geography at FET phase in the represented schools (n=112).

The data presented in Figure 4-15 indicate that many respondents cover grade 12 GIS curriculum concepts in the lower grades i.e. the CAPS are not being strictly adhered to (South African Department of Basic Education, 2011). The numbers show that only 50% of the participants teach the GIS processing core topics (statistical analysis; data integration; spatial query) in grade 11 and grade 12 and 13% (15 of 112) do not teach these core concepts at all.

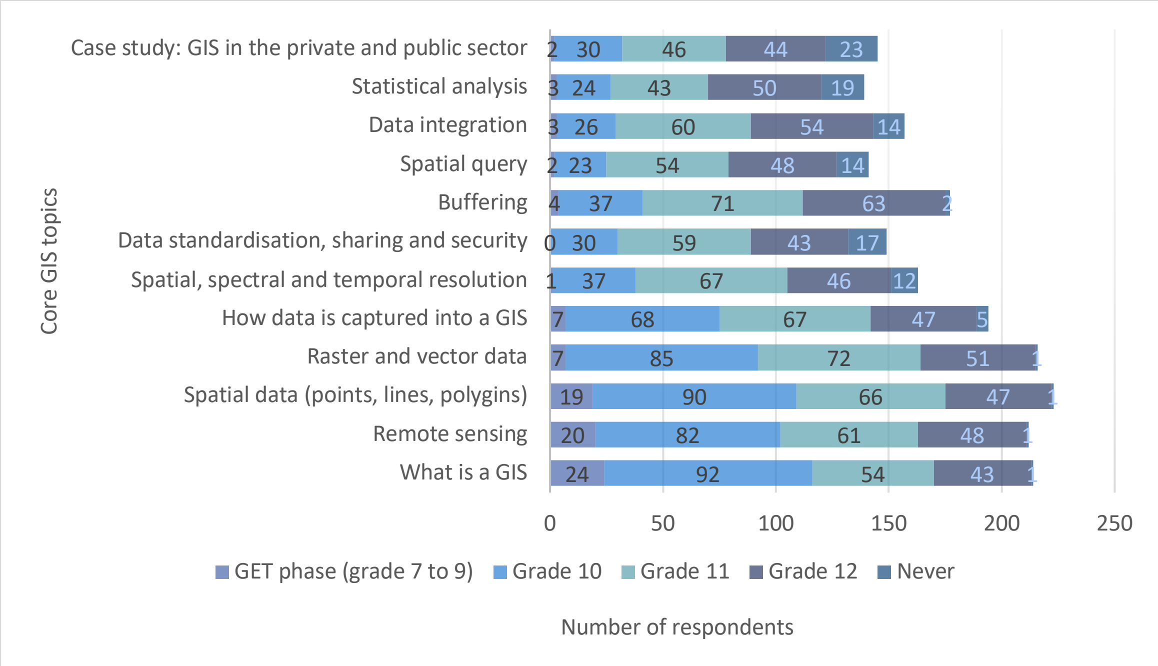

Figure 4-15: When GIS concepts are taught in the curriculum per grade and which core GIS curriculum topics (n=112).

The greatest technique used by the largest number of respondents to digitize spatial data is Paper GIS (83%; 84 of 103) followed by Google Earth (48%; 49 of 103). It is encouraging that 11% (11 of 103) of respondents have used OpenStreetMap (OSM) and 13% (13 of 103) have used QGIS (Figure 4-16).

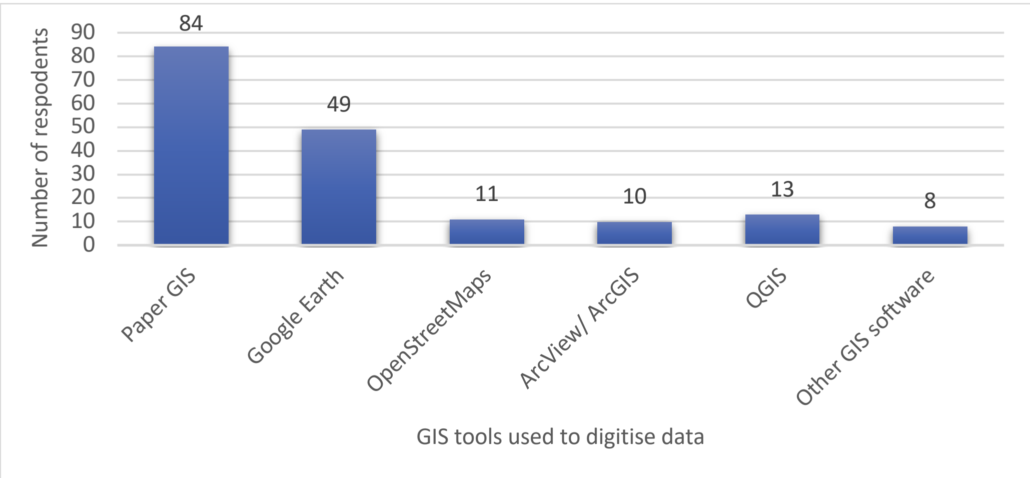

Figure 4-16: Techniques teachers use to digitise spatial data (n=103).

By far the greatest number of respondents (54.5%; 61 of 112) selected the seldom option, indicating that they teach GIS practical hands-on lessons less than once a year, if at all (Figure 4-17). Thirty eight percent (43 of 112) of teachers who responded indicated that they teach practical lessons more than once a year and only 7.1% (8 of 112) of participants indicated that they teach practical GIS lessons frequently (once a month or more).

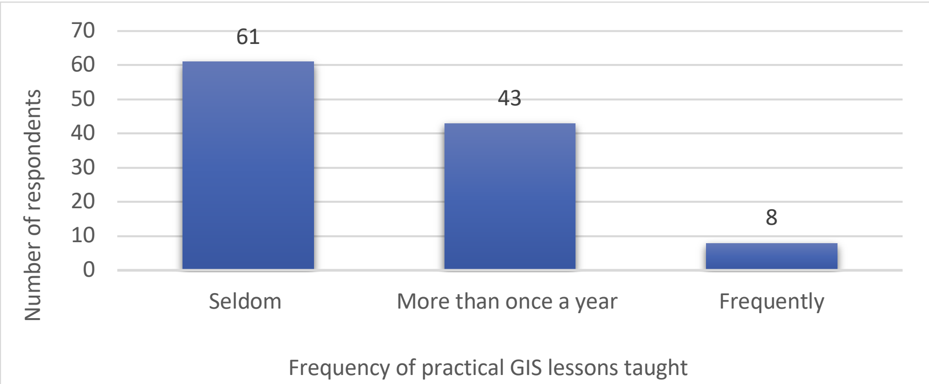

Figure 4-17: How often practical GIS lessons are taught in a school year (n=112).

The results in Figure 4-18 show that the vast majority of respondents have used GIS to teach map skills (85%), followed by Physical Geography (58%) then Human Geography (52%). Twenty eight percent of teachers have used GIS to teach case studies and in research projects. Twenty three percent of participants only teach GIS theory and do not use GIS to teach the curriculum. One respondent does not teach or use GIS.

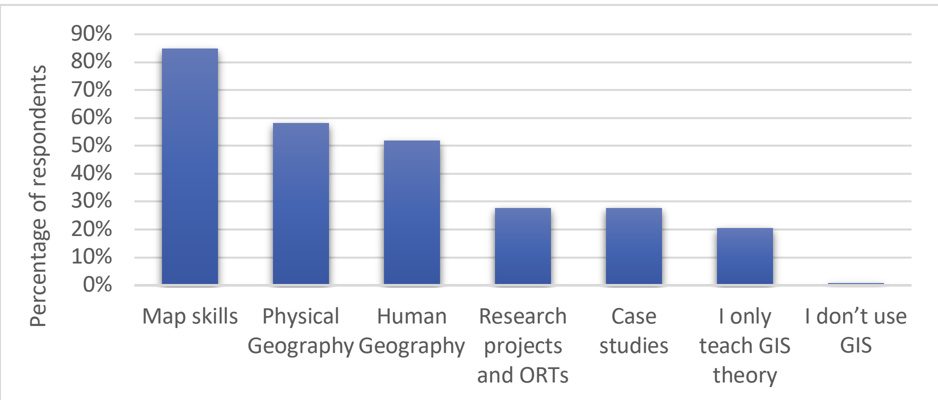

Figure 4-18: The section of the Geography curriculum where GIS is used to teach concepts (n=112).

The results for what resources the teachers who participated in the survey use to teach GIS, are summarised in Figure 4-19. The resources used most frequently are textbooks (77%; 86 of 112) and class notes (71%; 80 of 112), followed by digital presentations (44%; 49 of 112), teacher demos (37%; 41 of 112) and YouTube/videos (35%; 39 of 112). It is noteworthy that 44% (48 of 112) never invite guest speakers to come and talk about GIS nor do they use the IT lab. The reason for the infrequent use of the IT lab can be seen in Figure 4-9 and Figure 4-12.

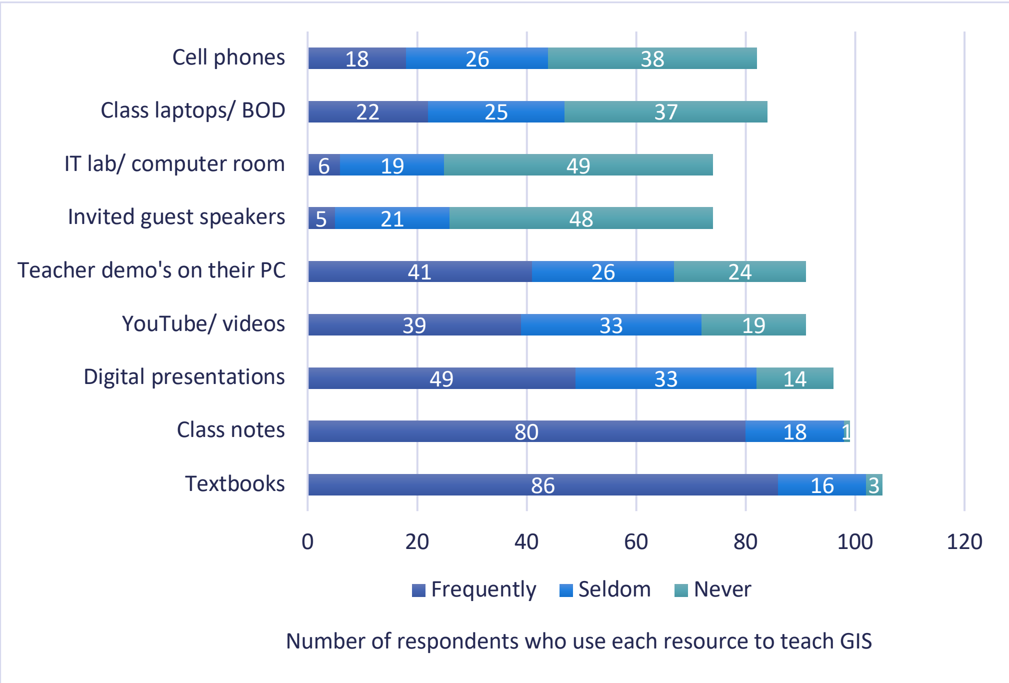

Figure 4-19: Available resources used to teach GIS in the classroom and frequency used (n=112). BOD refers to Bring your Own Device and PC refers to personal computer.

From Figure 4-20, it can be seen that the most used software used by teachers participating in the survey is Google Earth/ Google Maps (88%; 94 of 107); followed by Arcview/ ArcGIS (30%; 32 of 107) then QGIS (26.2%; 28 of 107). ESRI Story Map and OS Map Stories collectively have 16% (17 of 107) and Funda Lula has been used by 12% (13 of 107) of participants. The rest is negligible as less than two percent of the sample have used them.

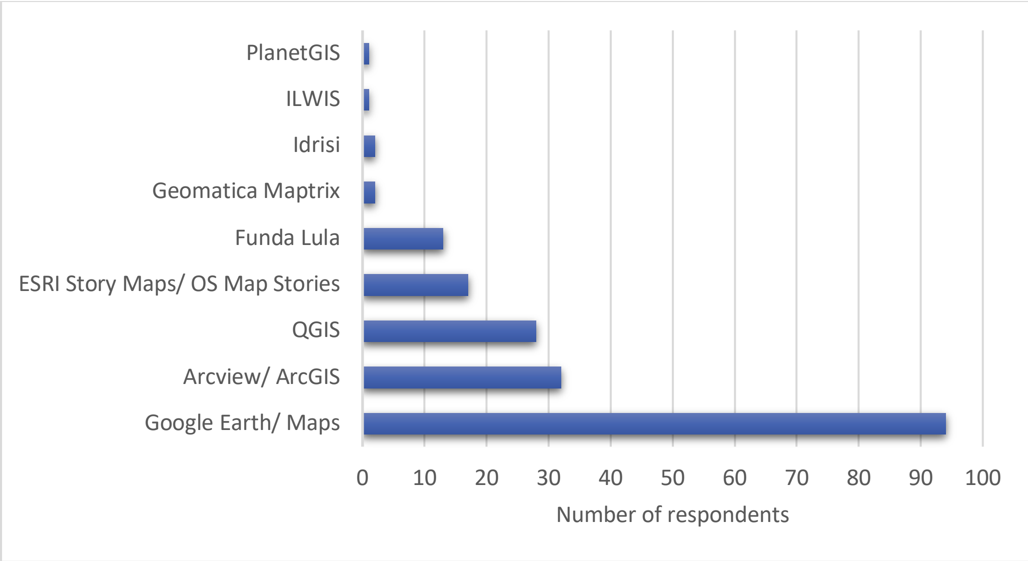

Figure 4-20: Software used by teachers to teach GIS (n=107).

What is encouraging for this research study is that more than 75% (62 of 112) of participants are interested in using GIS to help teach the Geography curriculum. Only 8% (9 of 112) indicated that they were not at all interested. This result is valuable in understanding teachers' attitude toward teaching GIS.

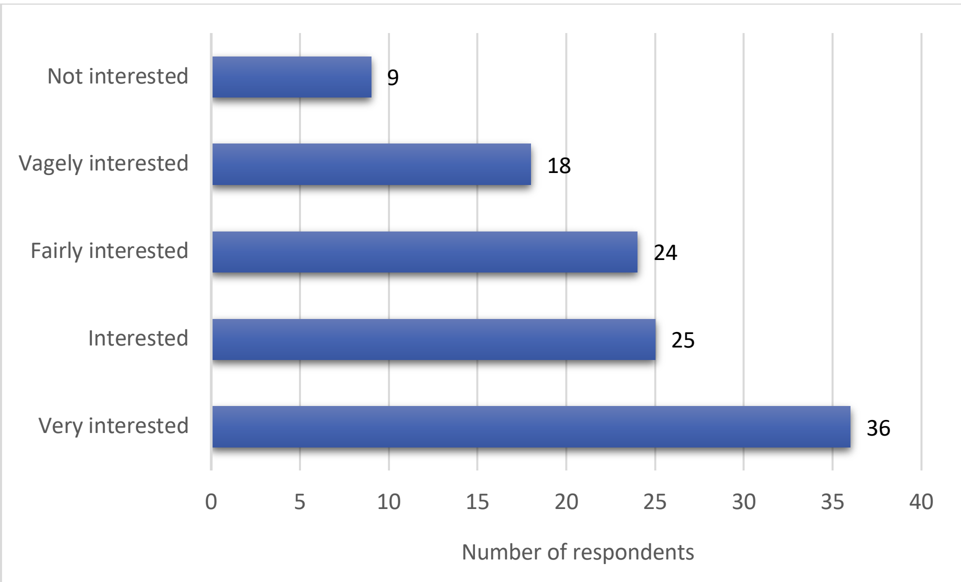

Figure 4-21: Level of teacher interest in GIS (n=112).

4.1.4 The level of teacher GIS experience and skills

The descriptive survey research questions in this section deal with GIS expertise, GIS courses attended, frequency of IT use, knowledge of OSM, interest in using GIS to produce maps for assessments, opinions, teacher reflections on why GIS is not used more frequently and why GIS should be used in Geography lessons.

In Figure 4-22 the majority (43%; 48 of 112) of participants rate their expertise on the Likert scale as fair. Fewer than 9% (10 of 112) rate their GIS skills as beginner and even fewer as expert (6%; 7 of 112). Less than a quarter of the teachers who completed the survey rate their skill level as workable (23%; 26 of 112) which may be a significant reason that so few Geography teachers teach practical GIS lessons (Figure 4-17). Nineteen percent (21 of 112) of teachers see their GIS expertise as good.

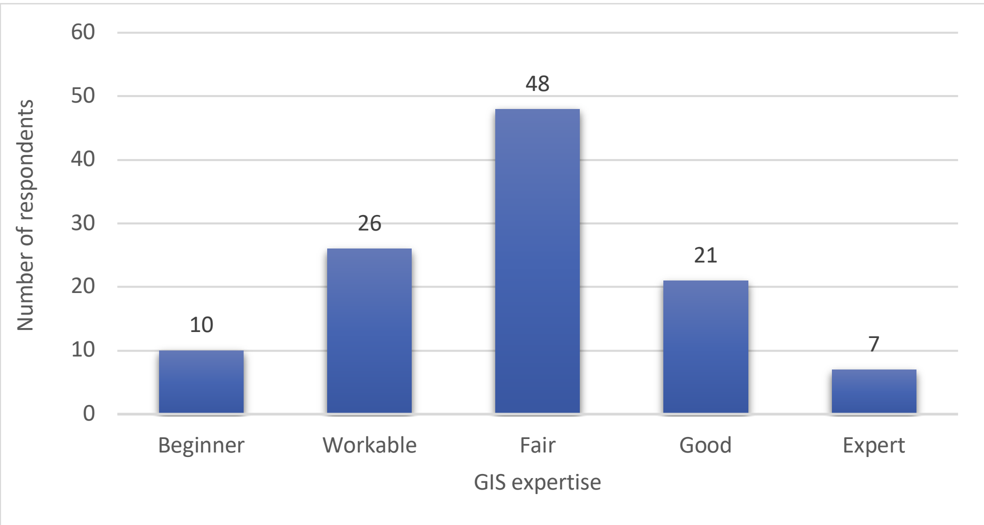

Figure 4-22: Level of teacher GIS expertise according to their own evaluation (n=112).

Exactly half of those who answered this question reported that they had attended a GIS short course by an independent service provider (50%; 56 of 112). Just over a quarter said that they had studied GIS in their undergraduate course (28%; 31 of 112) or were self-taught (27%; 32 of 112). Only 9% (10 of

112) of the participants had studied GIS at a post graduate level. Twelve percent (13 of 112) reported that they had no GIS training at all (Figure 4-23).

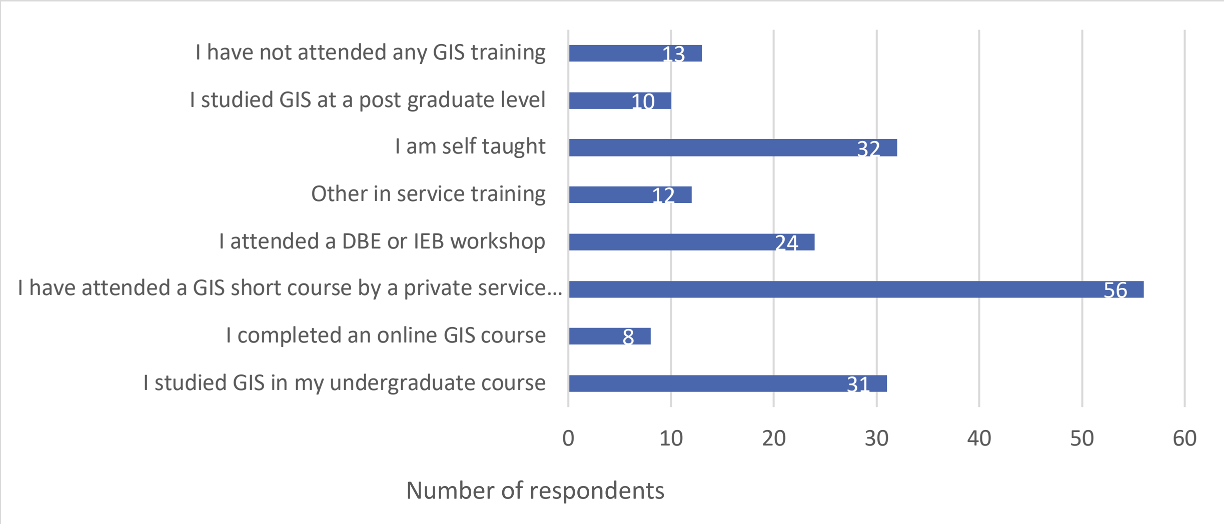

Figure 4-23: How teachers acquired training in GIS (n=112).

Only a small number of respondents indicated that they use ICT in every lesson (5%; 6 of 112); 33% (37 of 112) said that they use ICT often; 38% (42 of 112) indicated that they use ICT very rarely and nearly a quarter (24%; 27 of 112) do not use ICT in the Geography classroom (Figure 4-24).

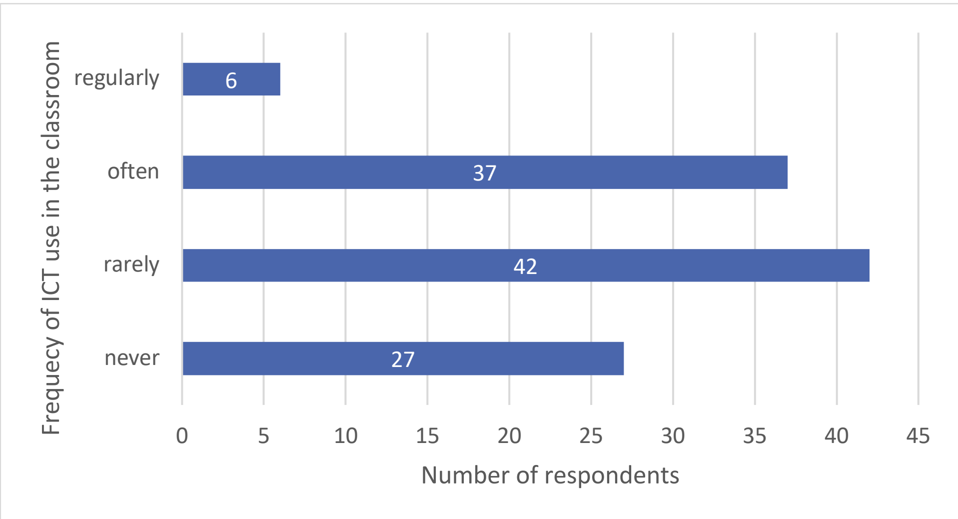

Figure 4-24: Frequency of ICT (Information and Communication Technology) use in the Geography classroom by respondent (n=112).

Half of the 111 teachers who responded to this item had heard of OSM, 43% (48 of 111) had not and another 6% (7 of 111) indicated that they had possibly heard of OSM (Figure 4-25). This result is similar to the qualitative interview answers when the teachers were asked the same question. Only four of the nine teachers interviewed indicated that they had heard of OSM.

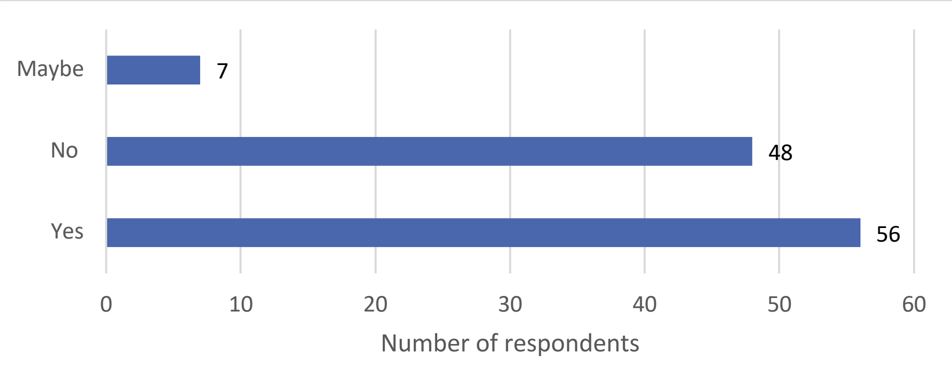

Figure 4-25: Has the respondent heard of OpenStreetMap (OSM), (n=111).

The majority (72%; 80 of 111) of the respondents said that they were interested in improving their GIS skills. The rest (27%; 30 of 111) were interested but either did not have the time nor the budget. Only one participant was not interested. When this result is compared to Figure 4-28: Reasons why GIS may not be used in Geography lessons, the vast majority of participants agree that teachers are not competent at using GIS software. It is encouraging to see the willingness to up-skill in GIS.

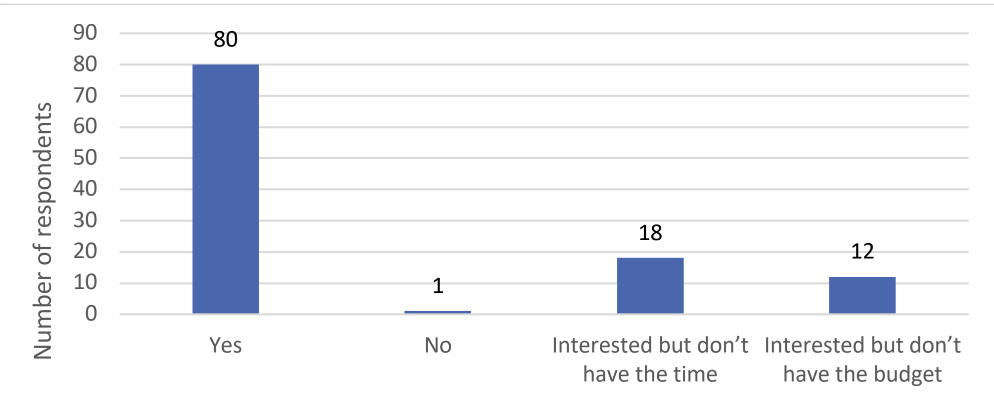

Figure 4-26: The number of respondents interested in improving their GIS skills (n=111).

When the participants were asked if they were interested in using GIS to produce maps for assessments, the majority (85%) indicated that they were (Figure 4-27).

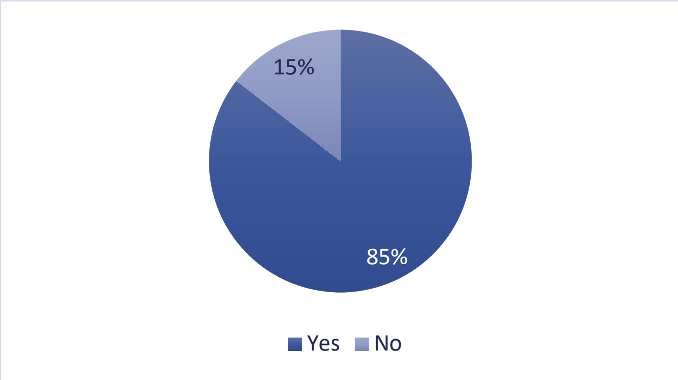

Figure 4-27: Teacher interest in using GIS to produce maps for assessments (n=110).

The vast majority of respondents (96%; 107 of 112) agree that teachers are not competent at using GIS software as a reason why GIS is not used in the Geography classroom. Eighty eight percent (92 of 112) agree that there is a lack of sufficient hardware and software followed by 82% (84 of 112) affirming that there is a lack of classroom environments suitable for the use of GIS. Sixty four percent (65 of 112) believe that teachers have a negative attitude to GIS and lastly the minority of teachers, 26% (29 of 112) indicate that GIS is too difficult to learn. The factor that ranks at the fore is teachers' competence with using the software (Figure 4-28).

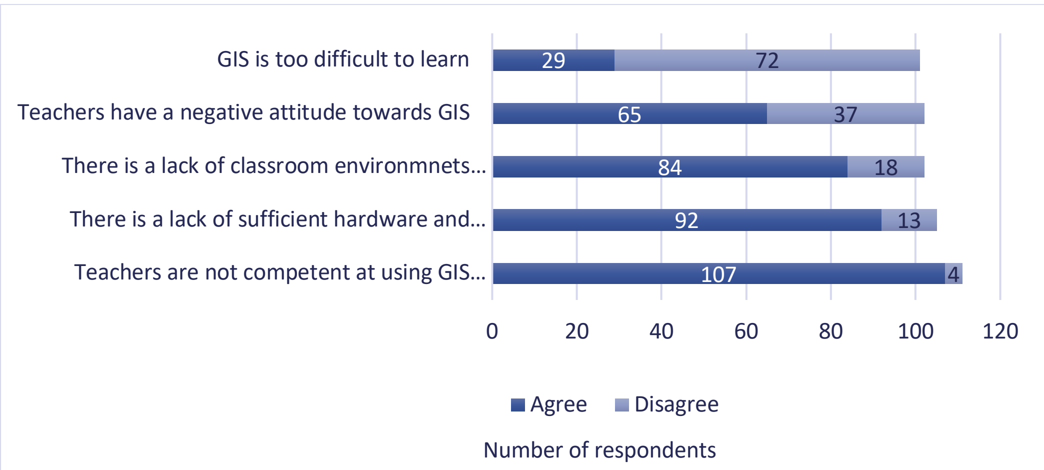

Figure 4-28: Reasons why GIS may not be used in Geography lessons (n=112).

The final survey question required participants to evaluate why GIS should be used in Geography lessons using a five-level Likert scale from strongly disagree (one) to strongly agree (five). The averages and standard deviation of these values from one to five for each reason was calculated (Table 4 2). The highest average (4.7) indicated that most of the participant strongly agree that GIS helps students to visualise geographic data. The reason that GIS facilitates the research enquiry process had an average of 4.4 and had the most number of impartial counts (13). The averages for all the reasons range from 4.4 to 4.7 indicating that the majority of respondents agree and agree strongly with the reasons listed as to why GIS should be taught in the Geography classroom (Table 4 2).

Table 4-2: Evaluation of reasons why GIS should be used in Geography lessons using a five-level Likert scale.

	strongly agree (5)	agree (4)	impartial (3)	disagree (2)	strongly disagree (1)	Total n	Ave (1 - 5)	95% Confidence Interval	Std dev
GIS allows for the comparison of geographic data	70	36	2	0	0	108	4.6	4.41 – 4.79	1.00
GIS helps students to visualise geographic data	76	33	2	0	0	111	4.7	4.57 – 4.83	0.67
GIS can be used to help explain geographic concepts	70	35	5	0	0	110	4.6	4.44 – 4.76	0.84
GIS allows for experimental learning	62	35	8	2	0	107	4.4	4.18 – 4.62	1.16
GIS facilitates the research enquiry process	62	34	13	1	0	110	4.4	4.22 – 4.58	0.94
GIS allows for student-centred teaching	59	36	10	2	1	108	4.4	4.19 – 4.61	1.14
GIS is a vital 21st century learning skill and helps students think critically	83	18	5	2	1	109	4.6	4.37 – 4.83	1.21

Figure 4-29 shows a comparison of the frequency of GIS hands-on lessons in the classroom (one being seldom to three being frequent) to how resourced the school is (one being under resourced to five being very well-resourced). The number of participants who seldom teach GIS practical lessons ranges from 7 to 15. The distribution is across all schools, regardless as to how resourced the school is. The same even distribution is true for the 8 participants who indicated that they teach GIS practical lessons frequently.

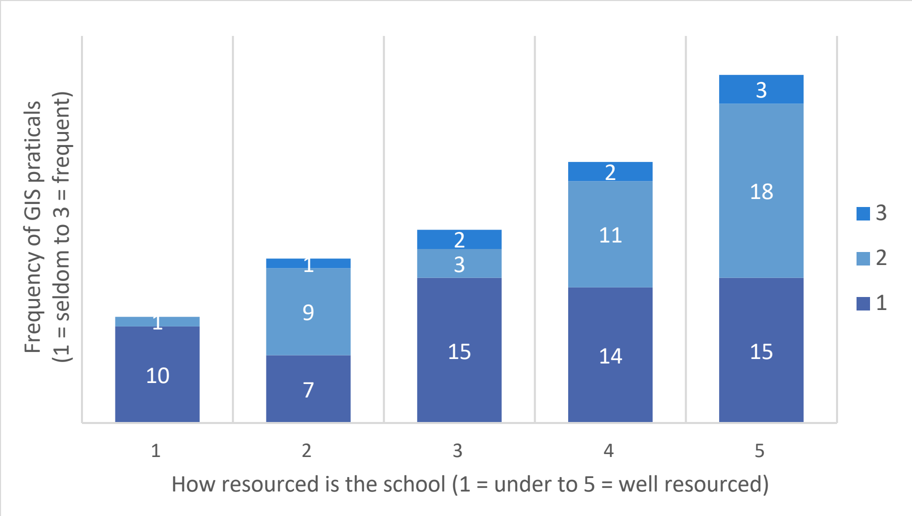

Figure 4-29 Comparing the frequency of practical GIS lessons (with 1 being seldom to 3 being frequent) to how resourced the school is (1 being under resourced to 5 being very well-resourced) (n=111).

As with the previous results, the frequency of practical lessons was compared with another set of results, in this case with the Examination Board of the participants to see if an inference could be made. The results show inconclusively that the Examination Board makes no significant difference as to how often GIS lessons are taught practically. Forty eight percent of DBE and 42% of IEB participants teach GIS practical lessons once a term or less (Figure 4-30).

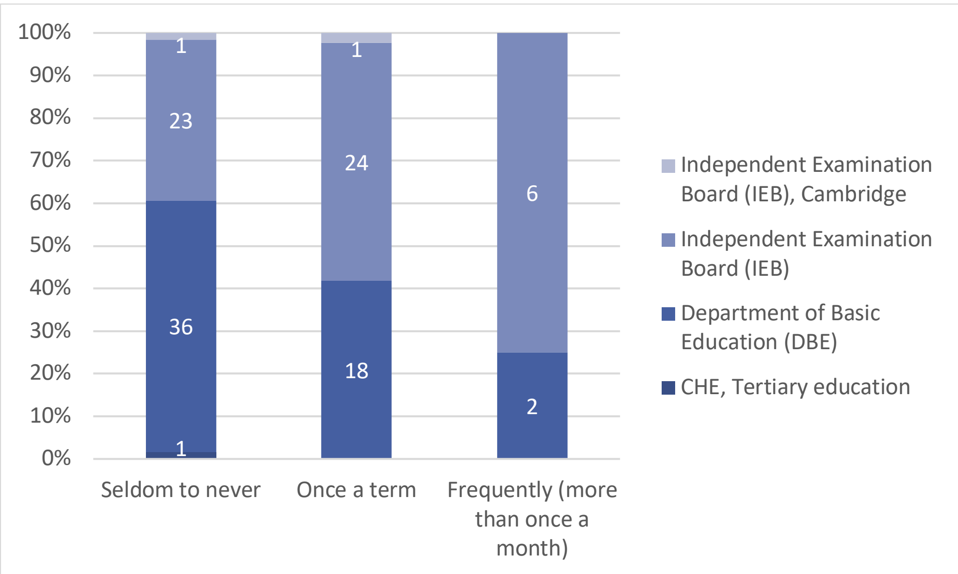

Figure 4-30: Frequency of practical GIS lessons taught compared to the Examination Board (n=112).

4.2 Research results from the interviews

The nine respondents interviewed were selected for their willingness to participate and their demographic profile. The researcher wanted a range of ages, experience, types of schools, Examination Board representation and a national spread. Each interviewee was contacted ahead of time and sent a consent letter (Appendix A) and the interview questions (Appendix D). Their respective Heads of School were also contacted to explain the purpose of the research and to request permission to interview their staff member. Interviews took place between October 2019 and March 2020. The researcher met with each in person and before the interview, demonstrated how OSM data and QGIS could be used as a teaching resource (Appendix E). Interviews were then transcribed by the researcher and common themes were identified and coded manually.

The tabulated results in Table 4-3 show a spread for the sample of participants interviewed from having less than one year's teaching experience to over 40 years. The majority of teachers (three candidates) having taught for 36 – 40 years. Similarly, results show a spread of participants teaching at boys only, girls only and co-educational schools. Two of the nine schools teach in a rural environment. Although all private schools, the majority (63%) teach IEB and 33% teach the DBE Examination Board.

Table 4-3: Respondents' profiles with the common variable highlighted. Interviewees' names have been replaced with letters from A to I and are listed in the order of when the interviews took place (n=9).

Interviews n=9	Years of teaching experience	Examination Board IEB/DBE	Type of school (All independent schools)	Province in SA
A	16-20 years	IEB	Urban Co-Ed	E Cape
B	< 1 year (student)	DBE	Rural Co-Ed	E Cape
C	36-40 years	IEB	Urban Boys	Gauteng
D	36-40 years	IEB	Urban Co-Ed	E Cape
E	> 40 years (retired)	IEB	Urban Girls	KZN
F	16-20 years	IEB	Urban Girls	Gauteng
G	11-15 years	IEB	Rural Co-Ed	W Cape
H	31-35 years	DBE	Urban Girls	W Cape
I	36-40 years	DBE	Urban Boys	W Cape

Respondents interviewed come mainly from four provinces in South Africa, 33% from The Western Cape, 33% from the Western Cape, 22% from Gauteng and 11% from KwaZulu-Natal (KZN). The interviewees' names have been replaced with letters from A to I to ensure anonymity. The location of the schools A to I are mapped using QGIS in Figure 4-31.

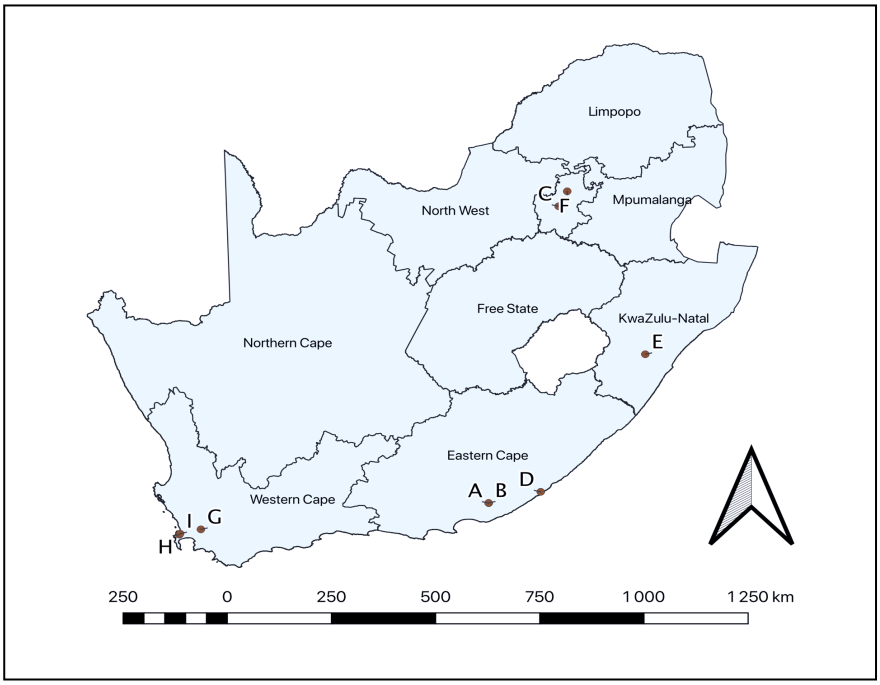

Figure 4-31: Map of South Africa showing location of schools for teachers interviewed by Province (produced with QGIS).

4.2.1 Themes identified from the interviews

Seven broad common themes were identified in the first interview question that asked participants what the advantages were to teaching GIS in the Geography classroom. Two others are mentioned to show different perspectives on the topic. Overwhelmingly, the majority of the interviewees (78%) commented on how GIS helps to teach topical and current issues and 67% said it helps to capture the interest of the pupils/learners. Forty four percent of the interviewees mentioned Theme Two (captures interest) Theme Four (connects disciplines/ multidisciplinary) and Theme Five (interactive/ 4IRs). Three participants mentioned opened up new career paths. Letters A to I were assigned to each participant to ensure anonymity.

Table 4-4: Interviewees A to I that mentioned common themes identified to the question what the advantages are of using GIS in the classroom (n=9).

Interviewee: / Themes:	A	B	C	D	E	F	G	H	I
1 Engages pupils	x	x							
2 Captures interest	x	x	x	x			x	x	
3 Evokes curiosity		x		x					
4 Connects disciplines/ multidisciplinary		x			x				x
5 Interactive/ 4IRs			x		x	x			x
6 Helps to teach relevant/ current and topical issues		x	x	x		x	x	x	x
7 Helps visual learners						x			
8 Makes it more accessible							x		
9 Awareness of new career paths			x			x		x	

The transcriptions for each interview were coded thematically and the interview quotes for the question that asked what the advantages are to using GIS were matched with each theme. These are listed in Table 4-5. The overall consensus among most participants is that GIS engages pupils, captures pupil's interest and helps to teach current and topical issues. Teachers liked the interactive aspect to practical GIS lessons and that it ticked the box for teaching 21st century learning skills of the fourth industrial revolution. They also commented on the career opportunities available for their pupils in GIS and therefore it was important to expose them to these new career paths. One interviewee commented that GIS makes Geography concepts "more reachable, attainable and usable".

Table 4-5: A list of identified themes from the first interview question (what are the advantages of using GIS in the classroom) and interviewee's quotes that match each theme. Letters A to I represent individual interviewees and their quotes taken from the transcriptions of their interviews (n=9).

Interview question 1: What are the advantages of using GIS in the Geography classroom?	
Themes	Interviewee's (A-I) quotes
1 Engages pupils	A - It will also help them understand and engage with more about the concept of the whole GIS and digital mapping
	B – GIS grabs their attention and as soon as you have their attention, then they're engaged.
	D - Much of the education is all for them is old world and consequently irrelevant to them most. They want an instant pressing up of getting the details and immediately making use of it so that would be bringing Geography in line with what is important in their lives, what serves them up and what is meaningful to them.
2 Captures interest	A - I've found that people, mainly the adolescents at that age love technology so anything that's going to involve computers or with the laptops they've interested in immediately and its joyous.
	B - Okay so what we have been shown as being important for the students is having something that's going to spark interest and curiosity.
	C - a chalk and talk approach to any kind of teaching leaves them cold and as soon as technology is introduced what it does it awakens them and it actually puts the learning in their hands.
	H - I think the biggest advantages of GIS is just makes them it makes Geography come alive
3 Evokes curiosity	C - as soon as technology is introduced what it does it awakens them and it actually puts the learning in their hands.
4 Connects disciplines/ multidisciplinary	B - The Geography in itself is interdisciplinary so it looks into the political, politics and it is multifaceted.
	E - it enables them to start connecting the dots
	I - What it does it take statistics, figures and converts it into images and it really makes it easier for the kids to understand numerous aspects of Geography
	C – the theory is taught through the children's practical application and self-discovery. So there's nothing worse than a printed piece of paper with black and white definitions etc. etc. You just show them the first step and before you know it they're running and suddenly they starting to use the terminology they're talking about polygons, they're talking about lines, they're talking about attribute data legends and so they especially internalising the theory inherently without knowing that they're actually learning because it's through

	excitement and discovery. Then they come back and so then you need to just reinforce certain aspects of the theory and it's chop-chop
5 Interactive/ 4IRs	D - I think that the kids are all smartphone psyched up and they are good with any kind of IT that the world that there are as current, instantaneous and they want solutions.
	F - I think the big thing in our school is that we focused on the four IR's and looking at what's ahead in the future and with GIS in the classroom when you can open those doors to the kids
	E - so when it comes to a map they've got no clue of the environment around them, and I think this makes it very interactive.
	I - for example I use it using Google Earth we've got KMZ files that generate hurricane path tracks.
6 Helps to teach relevant/ current and topical issues	B - So you can also use it for informal and formal assessment of the learners so things like geomorphology could be “outlined river floodplain” or something from an aerial photograph so could ask them to mark in the knickpoint.
	C - as soon as technology is introduced what it does it awakens them and it actually puts the learning in their hands. Excuse the pun but in their hands and it shows them today's relevance.
	D - they are good with any kind of IT that the world that there are as current.
	F - with GIS in the classroom when you can open those doors to the kids it's that you're taking the theory out of the book and putting it into reality
	G - I think GIS makes Geography more relevant to pupils in today's world …it's no longer just about sort of outdated maps with watermarks all over them which have been used a hundred times over it's actually about making it something that they own and making it relevant and interesting and accessible for them in the classroom which I love
	H – while field trips are very important we don't always have the time to go out there so GIS means that they can see real data out there and that real people are involved.
	I - We use it to teach landforms we use it for field trip projects we boys go on a field trip and they plot their position and create images that are put into Google Earth.
7 Helps visual learners	F - putting it into a perceptive view especially for the kids that are visual learners and then I have found to be a massive advantage for GIS.
8 Makes it more accessible	G - so much of our world is digital so much of our world is no longer paper and it makes it more it makes maps and information and data more reachable, attainable, usable for kids it's more accessible that's the word I'm looking for.
9 Awareness of new career paths	C - grab that opportunity to show them that what is relevant today technologically will be their future career tomorrow.
	H – they can see these real data out there are real people involved and I think the one thing is that it opens up this whole career path that nobody knew existed.

Six broad themes emerged from the analysis of interview transcripts from the second interview question that asked participants what the hurdles are to teaching GIS in the Geography classroom and one other is given for a different perspective (Table 4-6). More than 50% said that power supply and connectivity were two of the biggest hurdles. The next identified theme that most of the participants mentioned was lack of hardware and access to technology and lack of teacher GIS skills (44%). Three of the participants mentioned time constraints and a lack of enthusiasm on the part of the teacher and having mixed ability pupils in the classroom. The lack and complexity of GIS software was only mentioned by two participants.

Table 4-6: Interviewees A to I that mentioned common themes identified to the question what the hurdles are to using GIS in the classroom (n=9).

Interviewee: / Themes:	A	B	C	D	E	F	G	H	I
1 Lack of hardware access to technology	x	x			x	x			
2 Lack of software, complex to use	x		x						
3 Teacher skills			x	x	x			x	
4 Time/ only doing what the curriculum requires/ lack of enthusiasm							x	x	x
5 Connectivity/ power supply	x	x			x	x	x		
6 Mixed abilities in the classroom/ student absenteeism	x			x		x			
7 Lack of support from tech staff at school					x				

The transcriptions for each interview were coded thematically and the interview quotes for the question that asked what the hurdles are to using GIS in the classroom were matched with each theme. These are listed in Table 4-7. A variety of perspectives were expressed; however, the most common was the concern of power supply to teaching GIS as a practical subject in South Africa. This was of particular concern for the two interviewees teaching in rural schools. The theme of lack of hardware and access to technology being a hurdle to teaching GIS emerged as strongly as it did in the quantitative results section (Figure 4-13). One interviewee was very concerned with "teachers getting caught up with the curriculum checklist… And that often prevents (teachers) from extending it and going further". Time constraints, time to learn GIS skills, set up lessons, time to "play" with GIS as one person mentioned was a commonly mentioned hurdle to teaching GIS practical lessons.

Table 4-7: A list of identified themes from the second interview question (what are the hurdles to using GIS in the classroom) and interviewee’s quotes that match each theme. Letters A to I represent individual interviewees and their quotes taken from the transcriptions of their interviews (n=9).

Interview question 2: What **are** the biggest hurdles to using GIS in the Geography classroom?	
Themes	**Interviewee’s (A-I) quotes**
1 Lack of hardware access to technology	A - not all our pupils have their own laptops so they share. anyone has a laptop and access into QGIS
	B - It's the technology, it may just be for Grahamstown, as obviously the school has computer labs but in terms of the boys having their own laptops - maybe not even 50 percent have at a guess from what I saw. Maybe the Eastern Cape is just a bit more an extreme.
	F - then obviously your technology - you know the laptop problems and the Wi-Fi they're kind of things those are our issues, so that is more an IT issue rather than GIS issue.
2 Lack of software and GIS data, complex to use	A – if they borrow a laptop they don’t have access to QGIS
	C - from the point of view of gaining data secondly it was so complicated, that I myself was losing passion for the technology. And so I wasn't I was actually passing on a negative aspect to the class.
	D - I started using ESRI software and I found it very complicated. I've subsequently changed maybe for the last 6 years using QGIS. I was trained on QGIS one point naught so that is my understanding of GIS. ..in a two-week cycle we have one lesson where the kids go to the computer room and actually have a GIS lesson in the school but unfortunately they've got iPads all the kids have an iPad but at the moment QGIS as far as I'm concerned is just on laptops so that's a bit of a negative.
3 Teacher skills	E - I think it would be lack of capacity from teachers who don’t know enough
	H - I think I'm the biggest hurdle at the moment because I need to learn this and I don't get enough time as teachers don't enough time to sit and play around.
4 Time/ only doing what the curriculum requires/ lack of enthusiasm	G - .. the biggest hurdle is not getting caught up in probably the curriculum checklist because I think the curriculum checklist is very much, right you need to make sure that they understand the terms and definitions it's not it's very mundane and it's very boring and I think as a teacher you sometimes get caught in that cycle of okay I just need to go, I just need to make sure that they know I've ticked everything in the list and they know what that what they've done. And that often prevents you from extending it and going further …but then also the not getting bogged down in just the mundane curriculum part of it.
	H - I hate teaching the GIS theory from the textbooks because it's just dead, it's not alive and you're teaching and I mean for us yes maybe in grade 12 but I mean what are we teaching it for 15 marks (DBE exam) but they did have seen the value and so we need to get girls, not everybody can be a doctor man they can’t take the blood!
	I - I'd say the biggest impediment would probably be the teachers a lack of enthusiasm to teach the subject, probably because they intimidated by it and that obviously could be solved by training.
5 Connectivity/ power supply	A - So that would also be an issue (WI-FI) and the class is held up with everyone downloading
	B - data is expensive and they would need to buy the data in order to be online.
	E - then also you don’t have adequate facilities in a computer lab, nor do the learners all have access to Wi-Fi and connectivity within the school. So in school I taught at, the students are not allowed to use cell phones at school, so therefore their cell phones are not connected to the network … it's about connectivity and it's about having access to Internet
	F - then obviously your technology, the Wi-Fi
	G - I think one of the things is technology sometimes is not always sometimes you get caught up in the nitty-gritty of technology of does everyone have a charged device or can you get access to a computer lab when you share facilities with the whole school connectivity and no connectivity's being a major thing for us out here we've only just recently got fibre so and for a long time connectivity was not a given. Electricity is also assuring our classroom and our part of the world in our country.
6 Mixed abilities in the classroom/ student absenteeism	A – What I find is that some are different levels in the class so some will hold others back and you're trying to go through the work, some are working so quickly and others are a bit slower
	C - I found that a hurdle is that once I go into the technology and there's a child absent. I find that the continuity of my lessons gets affected, but then I came around that hurdle by using the boys to catch their peers up and that was so successful because not only was learning taking place but the child was also being a teacher-guide a mentor.

	F - The girls that are tech savvy don't need to be pampered all the way, they get through it much quicker than the girls that need a hand to hold and I think especially with our society and our type of climate is that our girls are used to having their hands held the whole way, so it's very slow..and it's a very slow process, but once they've got it, (GIS lesson) they've got it.
7 Lack of support from tech staff at school	E - In our school it would have been the techie staff because they know nothing about GIS, they don't understand it, they don't regularly update they only do it if we ask them to do it and nine times out of ten it's not done properly in the lab so we had to go and troubleshoot before we even got do a lesson.

Most interviewees (78%) mentioned that they would use GIS to teach Fluvial Geomorphology. Sixty seven percent of participants discussed local case studies and 44% mentioned that they would use GIS to teach Climatology and Settlement Geography. A third of the participants mentioned how they would use OSM and QGIS to teach GIS theory. Using GIS to teach map skills was only mentioned by one interviewee (Table 4-8).

Table 4-8: Interviewees A to I that mentioned common themes identified to the question where in the Geography curriculum and how could OSM be used to teach GIS practical lessons (n=9).

Interviewee: / Themes:	A	B	C	D	E	F	G	H	I
1 Map skills	x								
2 Case studies	x	x		x		x	x	x	
3 Fluvial	x	x	x	x	x	x			x
4 Climate	x		x	x				x	
5 Teach GIS concepts			x		x				x
6 Settlement		x			x	x			x

Whilst a minority of the participants interviewed (11%) mentioned that they would use GIS to teach map skills, this was the area in the Geography curriculum where most of the respondents said they used GIS (Figure 4-18). Many participants discussed local case studies, and some gave descriptive fieldwork ideas on how they would use OSM data in practical lessons. Many participants had used GIS when doing field work activities and I refer here to facilitating a study where the teacher (interviewee D) used drones and GIS to map water hyacinth encroachment (see quote D under Theme 3, Table 4-9). On the whole, the participants became very excited and enthusiastic when the researcher posed this question to them. These results suggest that there is a great deal of scope for using FOSS4G and OSM data as teaching interventions.

Table 4-9: A list of identified themes from the third interview question (where in the Geography curriculum and how could OSM be used to teach GIS practical lessons) and interviewee's quotes that match each theme. Letters A to I represent individual interviewees and their quotes taken from the transcriptions of their interviews (n=9).

Interview question 3: After observing the demonstration of how to use OSM local data and QGIS, where and how could GIS practical lessons be used to teach the curriculum.	
Themes	Interviewee's quotes
1 Map skills	A - I think from the map skills there's the opportunity with ortho-photos and you could bring in some real-life examples. I'd get my pupils to do for their own schools. I would use this (school name) map as we did an example but then I would give every people to do a certain area of the school and then from there they can just bring in the different aspects of theory and then they're practically using it while they're using it I would remind them of the GIS theory and I'll just recap through the whole practical session and I think to map the school be a good idea because it's interesting for them.
2 Case studies	A - You could bring in some real-life examples and just discuss interpretation of maps that aspect just use the actual map and then just from the with the example you spoke about yesterday humanitarian aid so with disasters you could discuss the recent disaster and put up an area look at this and lets map it but while we're mapping it let's just look at the destruction that has occurred and look at the area that's flooded.
	B - I always try reverted back to case studies because then if you do a case study thing that's going to make a more interesting. So then obviously you have constructing the map as a part of it, which we did but didn't survive in our third year we did a whole GIS course and we looked at data of a water body over time and then you had to map like the changing in the water like the water health by its colour as it picked up and the images and then you would mark a certain colour with your raster data in a certain block telling you about the health and understand the health of how the dam changed over the years.
	D - Our grade 12 have a GIS project as part of one of the tasks some of them by the third year depending on when they've come into the school haven't master those skills and then I basically have to give them another one. I do a case study like for instance if you are a government official in a location and you've got fires, how you preventing people from losing their livelihood in other words you look at issues like this gradient of the slope. I mean where the informal housing where does the river flow prone to flood. Where is their shack fires in which area and from that just identify the worst areas and the least. The worst areas are needing immediate attention and then you kind of grade that down so they need to plot in all those overlays
	F - Absolutely so for instance and my kids do a lot of them do rivers and so they always do the Google Earth image and they did the little plots on it with the pins and I had two girls come to me tonight and say yes but ma'am I can do this now with my River and I can change it and do this and that so already their brains are taking it from Google Earth which is something they've been using for a few years so now we can add to this
	G - Secondary research so just was so boring and so mundane and they don't actually learn much from it so primary research is really important and it's such an amazing skill. And with this (GIS) it would it would make a huge difference to them and being able to generate their own information actually, it makes a primary it gives them data, it gives them information which they can then refer to because that's often their biggest stumbling block with ORTs and research is what am I actually analysing. Where's this information that I need to read or analyse and if they are creating it themselves first it's ownership of it and pride look what I'm able to do but then they more engaged with they understand it better.
	H - with GIS I can do it electronically and so that we can actually position our in relation to will be currently are because I always say to them how can you know where you're going if you don't know where you come from. You need to know where we are first before we can look at where we are going. Because I mean I was looking at what's the place called Cano which is on the equator and it's West Africa and they all know about the Nigerians but they did not know that Cano was in Nigeria and I would not let go of the lesson until they could tell what country this was. But with GIS that just does it so quickly for them...

	I - yes you could you could teach for example geology you could for example we look at dip and strike of rocks we go to Mollie Point, so you could actually draw lines and particular angles and show them with the dip and strike. You can look at your geological features, you can map areas and look at environmental damage...
3 Fluvial	A - …and the fluvial aspects too - you could look at drainage basins.
	B - You could also look at river capture look at examples of river capture and if you have the data over period of time could actually showing this sequential sort of development.
	C - also the effect low-lying areas water, where flooding would take place, buffering all those all those concepts came through and we were in when we were doing fluvial geomorphology the whole concept of the oxbow lake and why it will form where it does or how it does is because of where through buffering an area is under threat of increased volume and where the flooding will take place and where the channel will start to straighten itself.
	D - Yes we're going to do the spread of the hyacinths in the Nahoon River, these holidays the kids have been doing a drone flights and from the drone flights because we've now got the University coming in to introduce insects to try and fight off the hyacinths so we're now tagging on to that project by giving them statistical data from Maps indicating what change has taken place and also having a bit as a base source
	E - I certainly think one can use it quite effectively you teaching fluvial geomorphology...
	F - … especially with buffering zones I don't think the kids understand buffering. I mean when we see that impact I was now for example the one think of is the Hartbeespoort Dam when they opened the gates now in December the flood gates and those rivers down the Crocodile R, how does that impact them you know we were all grateful for the water but what happened to the farms leading to Brits so I think it would be incredible, absolutely.
4 Climate	A - You could bring all that in while you actually look at the map with them, so some climatology …
	C - I mean right this year we had the most fantastic opportunity with the cyclone, Cyclone Dineo in there and we actually did that. We took time out of formal teaching time if you know and try sticking to the curriculum through in GIS and as they were working on it they were they were completely understanding not only the components, not only tropical cyclones per say...
	D - my goal by the end of the year is and I'm going to tackle it by looking at increased temperatures and fires and from that link to the alert that come from AFIS and just try and link it to this so to me that's how I was going to introduce the concept of digital mapping to my grade nines.
	H - But with GIS that just does it so quickly for them, you know, so and also, I mean I think we always think of GIS in terms of what's going on the ground, but it can actually be used to track what is going on in the atmosphere as well. But look it's a little tricky between hand this is together tracking this migration of the ITCZ and all of that you don't do that. It's a line so yeah you can use GIS in the atmosphere, it's not just on the ground.
5 Teach GIS concepts	C - From my point of view it's how to teach the theory the theory is taught through the children's practical application and self-discovery. So there's nothing worse than a printed piece of paper with black and white definitions etc. etc. You just show them the first step and before you know it they're running and suddenly they starting to use the terminology they're talking about polygons, they're talking about lines, they're talking about attribute data legends and so they especially internalising the theory inherently without knowing that they're actually learning because it's through excitement and discovery.
	E - I think it's very easy to use open street maps and by incorporating or exporting and pulling it into QGIS, it means you can actually do the GIS theory and I think it's a very practical hands-on and valuable experience, they don't have to learn it they understand it because I find that just even showing the layers on the slide on the screen they don't get the idea of information comes in themes or layers you can merge it together..
	I - Just the theory is pretty straightforward to teach because instead of learning just the terminologies that actually be able to see what those terms mean in terms of images or maps that you produce. So from that you tell them to generate a line, vector, point then they would know what does those features are and on a particular map. And then you could also go into data bases and show them how data bases are used to generate information, which is then translated from figures into to images, using symbology as well.
6 Settlement	B - Land change, I mean even in the example in the data we're looking at the literature, English literature Museum here in Grahamstown that wasn't there in 2012 so you can you use the data, you could see the extent of urbanisation.
	E - I also think that it will play a very important role in settlement Analysis. I think what might be very interesting is if one looked at formal business in any CBD and then you if you mapped informal business and tried to add that element and look at some of the relationships between the two and perhaps look at buffering and things like that we you could say actually this should not be allowed in the street because there's not enough space or there's too much traffic here so what you do to solve the issue of not being able to work on walk on pavements.
	F - Absolutely, so I would think the central place and being able to measure distances and apexes away from that if we did for instance I remember you a few years ago with there was a one IEB question on the KFC or the McDonald's and we've got five KFC's within a kilometre radius and if we went and interviewed them and saw where these kids you know because our sites and it's the students this is the (school name) one and you know what actually those people I think that would be incredible
	I - and look at streets where for example more vulnerable to crime. You could do a crime mapping map of your suburb based on information that you can get from your local security or the police station in the area and generate maps for people in that suburb and update them on a regular basis.

The results in Table 4-10 show that the majority of participants (67%) agree that their grade 12 learners or pupils could use QGIS and OSM data for their own research projects. Both the DBE and the IEB require grade 12 students to do a research project in Geography in grade 12 as part of their school-based assessment mark (DBE, 2018; Independent Examination Board , 2020). These projects involve the students identifying a local geographic issue and then using the enquiry process to research the issue for themselves. Two of the participants said that there was a possibility, and none said not at all. All the teachers interviewed expressed an interest after the demonstration was given to use the OSM and QGIS worksheets (Appendix E). This may be an opportunity for future research where a post survey is conducted with these teachers to evaluate the effectiveness of using OSM and QGIS in pupils/ learners' Geography research projects.

Table 4-10: Interviewees' (A to I) response to the question could their grade 12 pupils/learners use OSM data and QGIS for their own research projects (n=9).

Interview question 4: Could your pupils/learners use OSM and QGIS for their own Geography research projects (NSC and IEB)/ ORTs (IEB) in grade 12?									
Interviewee: / Answer:	A	B	C	D	E	F	G	H	I
Yes		x	x	x	x	x	x	x	
No									
Maybe	x								x
Quote/ Examples of projects	x			x	x	x	x	x	

Discussion

The first objective in this study was to determine how GIS is taught in the senior FET phase (grade 10 to 12) of Geography in secondary schools in South Africa and to determine the exposure that students have to practical hands-on GIS, through a desktop study of the literature and by conducting a survey with teachers. The next objective was to assess the resources available to teachers and schools, with which to teach GIS. A mixed methods research approach was adopted. Lastly, this research aimed to evaluate FOSS4G with QGIS software and OSM data as teaching intervention.

The cross-referencing of results helped with validation of respondents' answers (Creswell, 2009). The first research themes established the demographics of the participants; the type of school and resources available to the participants. The next research theme looked at how GIS was taught in the classroom and the last theme was used to establish the level of teacher competence to teach GIS and the GIS techniques and software used in the classroom (Table 3-1).

5.1 Who are the respondents?

The ratio of female to male respondents is approximately 2:1 for the online survey (n=112) and 1:1 for the teachers interviewed (n=9). This result correlates well with global trends according to UNESCO (2019). Fifty four percent of teachers in secondary education in the world are female and in southern Africa this figure is close to 60%. Teaching is predominantly a female profession with men mostly in senior positions (UNESCO Global Education Monitoring Report Team, 2019). Gender is not significant for the discussion in this research. However, this ratio does show that the sample is similar to global trends.

Although the current study had national coverage, there is bias to Gauteng (63%) and KwaZulu-Natal (16%) and no participants were from the N Cape. The online survey was posted on the SA Geography Teachers' mailing list where teachers sign up via word of mouth and which network was started in Gauteng (Southern African Geography Teachers Network, 2019). This may have limited the national spread of respondents.

It is significant that an equal number of the respondents follow either the Independent Examination Board (49%) or the Department of Basic Education (50%) examinations. This allowed for the data to be divided into two sample groups of similar size for comparing this data with other variables (Figure 4-30). Two of the respondents teach to Cambridge and another examination board and because this number is so small and therefore insignificant for this study, their curriculum will not be discussed here.

Figure 4-8 which shows the number of teachers that teach Geography at the participants' school is quite revealing in several ways. First, the fact that 19% of the respondents are on their own in the Geography department. Developing innovative GIS lessons on your own is difficult (Fleming, 2016). Second, is that the majority are in a department of two teachers (37%). The following inference can be made: That either the one senior teacher teaches FET and one junior teacher teaches grade 8 and 9 of the Senior Phase or that the classes are shared. The net result is that sharing ideas is difficult. Thirty four percent of participants have three to four teachers in the Geography department which is encouraging and ideal for sharing ideas on how GIS can be taught. What is also noteworthy and encouraging is that 9% have more than five teachers in the Geography department which is a robust environment for innovation and speaks to the popularity of the subject. Geography is an elective subject in the FET phase of secondary education in South Africa (DBE, 2018).

When the respondents' age distribution (Figure 4-4) is compared to the number of years of teaching Geography at secondary school (Figure 4-5) we see that 24% of respondents have taught for fewer than five years and only 30% are below the age of 30. This is significant as these results show that 52% of respondents have substantial teaching experience (over 20 years) but they would not necessarily have been taught GIS at tertiary level. This inference is made as GIS was only introduced in the mid-nineties in tertiary courses (Milson *et al.,* 2012). We can infer that if only 30% of respondents are below the age of 30 (Figure 4-4), that only a similar number would have studied GIS at tertiary level. When this result is cross referenced for validity with the results showing teacher qualifications, we see that 27.6% of respondents studied GIS in their undergraduate course (Figure 4-23).

The nine teachers interviewed came from four provinces around South Africa (Figure 4-31). The interviewees' distribution of teaching experience and urban/rural spread is similar to that of the respondents of the online survey. One deviation is that 33% came from DBE and 67% from IEB Examination Boards whereas as the respondents from the survey had an equal split (Figure 4-2). The interview respondents' profiles are summarised in Table 4-3. Other than the gender and Examination Board variations, the profile of respondents interviewed is similar to those of the larger sample which is what this study required for validity of their results for cross-referencing.

5.2 How prepared are teachers to teach GIS?

The majority (43%) of participants rate their expertise on the Likert scale as fair and only 6% as expert (Figure 4-22). These results are consistent with those of Collins and Mitchell (2020) who, when they asked their participants a similar question, 50% felt that they were "pretty literate" and very few rated themselves as expert, for a study done in USA. The findings of the current study show that just over a quarter of the respondents had studied GIS in their undergraduate course (28%) or were self-taught (27%). Only 9% of the participants had studied GIS at a postgraduate level and 12% reported that they had no GIS training at all (Figure 4-23). Collins and Mitchells' (2020) research suggests that GIS teacher professional development is essential if long-term classroom implementation of GIS is to be realised. There is therefore a legitimate need for teacher professional development in GIS in South Africa. This finding is in agreement with Zondi *et al*. (2020) and Mzuza *et al*. (2019).

Respondents were asked to indicate what GIS courses they had attended, what GIS techniques they used, what software they had used and how often GIS was used in practical lessons? The data sets were cross-refenced and a number of interesting results emerged. Firstly, the majority of teachers surveyed had attended a range of GIS courses but very few at a postgraduate level. A significant number of the respondents had taught for fewer than five years and this may explain why nearly a third had studied GIS in an undergraduate course. Fifty percent had attended short courses and 33% were self-taught. However, the majority of respondents still indicated the need to attend more professional development courses as the results show that paper GIS was mostly taught at secondary level and very seldom were practical GIS lessons taught in the classroom (Figure 4-17). These findings are consistent with other recent research done in South Africa (Eksteen *et al.,* 2011; Wilmot & Dube, 2016; Fleischmann & van der Westhuizen, 2017; Mzuza & Van Der Westhuizen, 2019; Zondi & Tarisayi, 2020).

5.3 What GIS-enabling resources do teachers have access to and what would teachers like to have access to?

The resources used most frequently are textbooks (77%) and class notes (71%) (Figure 4-19). Surprisingly, only five percent of teachers use the IT lab or computer room. When this result is compared to that of how frequently practical lessons are taught (Figure 4-17), it makes sense that the greatest number of respondents seldom teach GIS on a computer: less than once a year if at all. The low availability of ICT to teachers shown in (Figure 4-9) and the competence of teachers (Figure 4-22) to teach GIS could be two other possible reasons why practical GIS is so seldom taught.

Seventy eight percent of participants have their own laptop and a further 22% have the use of the IT lab and computer room (Figure 4-6). When compared to the high percentage of participants that "seldom" teach practical GIS lessons (Figure 4-17), the answers from the qualitative interview question make sense and the results correlate with and corroborate these results. Only four of the nine participants interviewed discussed access to ICT as a hurdle to teaching GIS (Table 4-6). Comparing these results to those in Figure 4-10, the opinion of the participants shows that 35% would like access to hardware. The results for Figure 4-12, which displayed how accessible the school IT lab is for teachers, were cross-refenced with the results showing what hardware was available to teachers (Figure 4-9). Of the 22% of participants who have access to a computer lab, this does not necessarily mean that it is always available to the teacher.

Using Excel pivot tables, data from Figure 4-6 was compared with data from Figure 4-17 to produce the compilation of these results in Figure 4-29. No GIS practical lessons are taught in under-resourced schools, which is understandable. However, the most striking result to emerge from comparing the data is that of participants teaching in schools on the next scale up (schools missing resources): 75% of these participants attempt practical GIS lessons.

Many respondents (40%) mentioned that improved connectivity would make GIS more accessible in the classroom (Figure 4-13). Results show that 13% of respondents do not have access to Internet (Figure 4-11). With no Internet, options for software that need to be online are not an option and downloading data is not possible. This result is similar to that of Figure 4-7, which shows that 14% of respondents service rural communities so perhaps there is a link to service provision in rural communities and access to Internet.

The majority (79%) of participants indicated that they would like GIS courses and practical GIS lessons (Figure 4-10) and when cross-referenced with the open ended answers in Table 4-1, 41% of the participants asked for practical lessons and courses. GIS practical lessons are also a theme that emerged in the qualitative interview results. Another common theme that emerged in the open-ended answers is the needs for an easy to use solution for software (19%). Fifty nine percent requested notes and lessons for GIS theory (Figure 4-10). However, only five percent of the participants who, when asked for similar in the open-ended answers, mentioned notes (Table 4-1). What is interesting is the answer from one participant requesting “standardised notes” and “concise outlines of what syllabus expects” as this may indicate that teachers do not feel confident to produce their own GIS material.

Respondents were asked how GIS could be made more accessible in the Geography classroom (Figure 4-13). By ranking the importance of each according to how the respondents answered, an interesting picture emerges. Most respondents see access to pre-designed GIS lessons as important (66%); second is training in the use of GIS software (62%); third is access to local GIS data (54%); fourth is cheap or free GIS software (52%); fifth is better access to hardware (42%) and lastly is better Internet connectivity (41%) which correlated well to the results in Figure 4-11 which shows the level of Wi-Fi connectivity at the participants’ school. The significance of these findings is that teachers do not perceive hardware or Wi-Fi connectivity but rather access to GIS lessons and training as what would make GIS more accessible in the classroom.

When respondents were asked what GIS resources they would like access to, the majority asked for practical GIS lessons. This also came up in the open-ended discussion question (Table 4-1). Figure 4-16 shows the results of techniques teachers use to digitise spatial data. It is encouraging that 11% of respondents have used OpenStreetMap (OSM) and 13% have used QGIS. None of the nine teachers interviewed had used OSM. Comparing this with how many teachers involved in this survey have heard of OSM (51%), it is surprising that so few have used OSM as a digitising source as OSM has the benefit of being free, accessible and is an easy way of obtaining local spatial data (Figure 4-25).

5.4 What are the advantages and challenges of teaching GIS?

A recurrent theme in the interviews was a sense amongst interviewees that teaching GIS in the classroom had a number of benefits (Table 4-4). When asked the question what the biggest advantage was of using GIS in the Geography classroom, the first theme that was identified was that GIS engages pupils. As one interviewee put it: “GIS grabs their attention and as soon as you have their attention, they're engaged”.

The second theme identified is that GIS captures the interest of pupils. For example: respondent C said, “…a chalk and talk approach to any kind of teaching leaves them cold”; and respondent H said, “I think the biggest advantages of GIS is it just makes Geography come alive”. The next theme is similar, that GIS evokes curiosity: respondent C said, “...as soon as technology is introduced what it does it awakens them and it actually puts the learning in their hands”. From these comments it is apparent that the interviewees believe that GIS will enhance learning in the classroom.

Interviewees also expressed the theme that GIS connects the disciplines. For example: respondent E said, “GIS enables them (pupils) to start connecting the dots” and respondent I said, “What it does is take statistics and figures and converts them into images and it really makes it easier for the kids to understand numerous aspects of Geography”. They also identified the interactivity of GIS as a big advantage: respondent D said, “the students are good with any kind of IT, especially what they see as current or instantaneous and they want solutions.” And respondent F said, “I think the big thing in our school is that we focussed on the 4IR's and looking at what's ahead in the future and with GIS in the classroom when you can open those doors to the kids”. These comments suggest that GIS is a technology enabler.

The majority of interviewees talked about the fact that GIS helps to teach relevant, current and topical issues. The following are quotes from interviewees under this theme: respondent G said, “I think GIS makes Geography more relevant to pupils in today's world …it's no longer just about sort of outdated maps with watermarks all over them which have been used a hundred times over it's actually about making it something that they own and making it relevant and interesting and accessible for them in the classroom, which I love”; respondent H said, “…while field trips are very important we do not always have the time to go out there so GIS means that they can see real data out there and that real people are involved”; respondent F said, “…with GIS in the classroom when you can open those doors to the kids, it's that you're taking the theory out of the book and putting it into reality" and respondent D said, "They (the pupils) are good with any kind of IT. GIS shows them the world that they are (live) in, as current". Relevancy is an important theme that emerged and most interviewees discussed this at length. Linked to this was the advantage of awareness of new career paths: respondent C said, "…grab that opportunity to show them that what is relevant today technologically will be their career tomorrow" and respondent H said, "they can see these real data out there and that there are real people involved and I think the one thing is that it opens up this whole career path that nobody knew existed". Teachers identified careers in the geospatial industry as being an exciting prospect for their pupils/learners and that was important for them to be exposed to these opportunities.

Two interviewees discussed advantages to using GIS in the classroom, that was not a common theme but noteworthy and consequently deserves to be mentioned: respondent F said, "GIS put it into a perceptive view especially for the kids that are visual learners and then I have found to be a massive advantage for GIS" and respondent G said, "…so much of our world is digital and so much of our world is no longer paper-based and it makes it more difficult to use maps and information. And data is more reachable, attainable and usable for kids. It's more "accessible", that's the word I'm looking for". Accessibility and that GIS made the subject come 'alive' was perceived as an important advantage to teaching GIS.

When compared to the results of the quantitative online survey (Table 4-2) ranked in order of percentage of numbers who agreed, the overwhelming majority of participants agreed that GIS helps students to visualise geographic data (98%); GIS allows for the comparison of geographic data (98%); GIS can be used to help explain geographic concepts (95%); GIS is a vital 21st century learning skill and helps students think critically (93%); GIS allows for experimental learning (91%); GIS allows for student-centred teaching (88%) and lastly that GIS facilitates the research enquiry process (87%). The average score for these results is 4.6, showing that, when asked to comment on the five-level Likert scale from strongly agree to strongly disagree, at the 95% confidence interval, it is statistically significant that the majority of the participants have the same opinion (Table 4-2).

A number of issues were identified as hurdles to using GIS in the classroom and these themes are summarised in Table 4-6: The first theme identified was the lack of hardware and access to technology. As one interviewee put it: “It's the technology, it may just be for Grahamstown, as obviously the school has computer labs but in terms of the boys having their own laptops - maybe not even 50% have at a guess from what I saw. Maybe the Eastern Cape is just a bit more an extreme”. The next theme identified was the lack of software and GIS data and that the software was complex to use. This also came up in the results discussed in the quantitative results in Figure 4-13 which showed factors that would make GIS more accessible in the Geography classroom.

Some interviewees argued that: respondent C said, “… from the point of view of gaining data secondly it was so complicated, that I myself was losing passion for the technology. And so I was actually passing on a negative aspect (attitude) to the class” and respondent D said, “When I started using ESRI software, I found it very complicated. I've subsequently changed maybe for the last 6 years using QGIS. I was trained on QGIS one point naught so that is my understanding of GIS. In a two-week cycle we have one lesson where the kids go to the computer room and actually have a GIS lesson in the school but unfortunately they've got iPads all the kids have an iPad but at the moment QGIS as far as I'm concerned is just on laptops so that's a bit of a negative”. Respondent G quite honestly suggested that his/her own lack of skill is a hurdle to teaching GIS when he/ she said, “I think I'm the biggest hurdle at the moment because I need to learn this and I don't get enough time as teachers don't enough time to sit and play around”. Furthermore respondent E said, “I think it would be lack of capacity from teachers who don’t know enough”. Comparing these quotes with the survey results (Figure 4-22) teachers not having sufficient skills to teach GIS becomes a recurrent theme.

One interviewee (respondent G) from a rural school stated that connectivity and power supply are significant obstacles by saying: “I think one of the things is technology sometimes is not always clear and sometimes you get caught up in the nitty-gritty of the technology and seeing if everyone has a charged device or can you get access to a computer lab when you share facilities with the whole school connectivity and no connectivity being a major thing for us out here. We've only just recently got fibre so and for a long time connectivity was not a given. Electricity (supply) is also erratic in our classroom and our part of the world in our country". Others also mentioned the high cost of data as transferring spatial data sets uses a significant amount of data. The majority of the interviewees expressed an interest in using OSM to access data (Table 4-10) and high data costs could be a prohibiting factor.

Whilst a minority (respondent I) mentioned that "I'd say the biggest impediment would probably be the teachers lack of enthusiasm to teach the subject, probably because they are intimidated by it (GIS)", all agreed that this could be solved by training. The online survey showed that the overwhelming majority of teachers expressed a willingness to learn more about GIS (Figure 4-26). The findings of the current study are consistent with those of others in that teacher training in GIS is what is needed for long-term success (Tate & Jarvis, 2017; Degirmenci, 2018; Hong & Melville, 2018; Healy & Walshe, 2019). One of the teachers interviewed in Collins and Mitchells' (2020) study confessed that time, and trying to cover the curriculum, were some of the biggest hurdles to teaching GIS and in this study the same theme was identified. One of the interviewees (respondent G) in the current study said, "the biggest hurdle is not getting caught up in the curriculum checklist".

The last theme identified is the lack of support from technical staff at school with respondent I saying "In our school it would have been the techie staff because they know nothing about GIS, they don't understand it, they don't regularly update they only do it if we ask them to do it and nine times out of ten it's not done properly in the lab so we had to go and troubleshoot before we even got do a lesson". It becomes clear that the lack of technical support leads to teachers avoiding practical GIS lessons.

The final survey question required participants to evaluate why GIS should be used in Geography lessons using a five-level Likert scale. With the majority of respondents agreeing strongly with all the reasons given as to why GIS should be taught and the majority (72%) expressing a willingness to improve their GIS skills (Figure 4-26), the future for GIS being taught more is encouraging. The most striking result to emerge from the data as to why GIS is not taught in the classroom (Figure 4-28) is that 96% of participants agree that teachers are not competent at using GIS software, as a reason why GIS is not used in the Geography classroom. However, more research on this topic needs to be undertaken before the association between frequency of practical GIS lessons and the availability of resources is more clearly understood. Current research of studies in South Africa in rural schools only refer to human capital (Wilmot & Dube, 2016; Zondi & Tarisayi, 2020).

In a study of how GIS was implemented in thirty-three different countries, Kerski *et al.* (2013) stated that he found South Africa's GIS curriculum one of the only that included geoprocessing that required pupils to apply data acquisition, management, manipulation and GIS analysis. The most widely taught geoprocessing concept taught is 'buffering' (Figure 4-15). This may be due to it being directly assessed in the NSC Geography examination for both DBE and IEB. The results do show a good progression of GIS concepts taught across the grade, which is how the curriculum was designed (Eksteen *et al*., 2012). This study concurs with Kerski's *et al.* (2013) findings and those of more recent studies (Wilmot & Dube, 2016; Akinyemi, 2016; Fleischmann & van der Westhuizen, 2017; Degirmenci, 2018; Mzuza & Van Der Westhuizen, 2019; Zondi & Tarisayi, 2020) that the reason for GIS not being taught effectively at secondary level may be attributed to lack of skills (teacher competence), time constraints, teacher perceptions of how complex the software is to use and the status of Geography at schools.

The results for the last survey question using a Likert 5-level scale that an overwhelming majority (98%) of teachers agree and agree strongly that GIS adds value to Geography classes (Table 4-2). The barriers to the implementation of GIS are similar to Scheepers (2009) and Demircis' (2011) study nearly ten years ago and the results of the interviews show that time constraints, teacher skills and access to meaningful spatial data are some of the biggest hurdles to teaching GIS effectively. Recent studies also refer to a lack of formal training in GIS and the results in this study show the same (Degirmenci, 2018; Healy & Walshe, 2020). The majority (96%) of teachers interviewed in this study refer to the lack of effective teacher training and not being competent as using GIS software as being a barrier to GIS practical lessons (Figure 4-28).

Teaching GIS in the classroom has both technological and societal challenges. Technological challenges include access not only to computers that have enough internal and graphics memory, hard disk space, and the proper software to be able to handle spatial analysis, but also to those computers in the school and support from the school's information technology (IT) staff (Kerski *et al.,* 2013). One of the participants interviewed discussed at length that the IT staff at their school were their biggest hurdle to using GIS (Table 4-7).

5.5 What is the feasibility of using FOSS4G tools in the Geography classroom?

An evaluation of FOSS4G OSM data and QGIS as teacher interventions was a key part of this study. Interviewees were asked to give comments (after observing how to download OSM local data of their school using QGIS software) on how they would use this to teach GIS theory and how else it can be used to teach the curriculum. One unanticipated finding was that the majority of respondents have used GIS to teach map skills (84.8%) (Figure 4-18). When compared to the qualitative interview research findings, only 11% discussed using GIS to teach map skills. 28% of teachers indicated that they have used GIS to teach case studies and in research projects. Almost a quarter of the participants (23%) only teach GIS theory and do not use GIS to teach the curriculum. Contrary to expectations considering so little practical GIS is taught, an overwhelming 75% of participants are interested in using GIS to help teach the Geography curriculum and only 8% indicated that they were not at all interested (Figure 4-21). This is significant as it highlights the willingness of teachers to learn more about GIS and the need for GIS teacher training in South Africa.

When asked if the respondents had heard of OSM, 50% said they had heard of it and 25% of the respondents had used QGIS before. In order to evaluate the effectiveness of FOSS4G tools such as QGIS and OSM data the nine teachers interviewed were shown a demonstration of a sample lesson. All interviewees expressed an interest to use these in class and their examples were tabulated in the results sections. It is recommended that further research be undertaken in a follow up study with the same sample of teachers' pupils to fully evaluate the effectiveness as this study only asked for the opinions of the teachers.

All the interviewees became animated thinking about examples of how QGIS and OSM could be used to teach the curriculum. The majority mentioned the advantages of teaching GIS concepts with FOSS4G tools as one interviewee (respondent E) commented "I think it's very easy to use OpenStreetMap and by incorporating or exporting and pulling it into QGIS, it means you can actually do the GIS theory and I think it's a very practical hands-on and valuable experience, they don't have to learn it they understand it because I find that just even showing the layers on the slide on the screen they don't get the idea of information comes in themes or layers you can merge it together". These results are summarised in Table 4-9 and agree with the findings of Bearman *et al*. (2016) in their study of how effective GIS education is in creating critical thinkers and Ciolli *et al*. (2017) in their research of the advantages of using FOSS4G tools in education. Ciolli *et al.*'s (2017) study suggests that FOSS4G should be encouraged more and more for ethical implications in that Open Software accessible to everyone and not only those who can afford propriety software and for cost saving reasons.

Seventy eight percent of the interviewees agree that their learners or pupils could use QGIS and OSM data for their own research projects (Table 4-10). Respondent G commented: "…with this (GIS) it would make a huge difference to them and being able to generate their own information …it gives them information which they can then refer to because that's often their biggest stumbling block with ORTs and research". Twenty two percent of the respondents agreed that there was a possibility and none said not at all. All expressed an interest to show their learners/pupils how OSM and QGIS could be used for research projects after the demonstration was given. This is significant as it provides an opportunity for further investigation.

5.6 What is the future of GIS education?

Collin and Mitchell's (2019) interview methodology and analysis of teacher attitudes was useful for this study. Many of the teacher responses there were similar to what teachers said in this study, which illustrates the global similarities with teacher attitudes to GIS. Their interview sample was similar to this research (18 teachers originally participated in their research but only 8 completed the full sequence of activities) and the range of teaching experience of the sample group was from three to thirty years, as it was with the teachers interviewed for this particular research. Collin and Mitchell's (2019) paper gives an interesting perspective on how common many of the issues are with teaching GIS in the classroom in South Africa and in the United States such as the need for pre-service training in GIS; lack of time; pressures of the curriculum and how few schools use GIS in the classroom. Their study used ArcGIS online as a teaching tool whereas this study used FOSS4G software and OSM data.

Student-centred learning and project-based learning (PBL) were not effective without extensive teacher training (Sinha *et al.,* 2016; Ciolli *et al.,* 2017). Others such as Hong & Melville (2018), Degirmenci (2018) and Healy & Walshe (2019) suggest that effective GIS adoption requires hands-on learning and time to master the skills. It is recommended that to achieve long-term success, training beyond merely the awareness of what GIS is, is required (Collins & Mitchell, 2019). This was a common theme when interviewing the teachers for this research and the results from the online survey corroborated this. Teachers overwhelming agree that the lack of teacher competence in using the GIS software results in the low adoption of using GIS in the classroom. The results show that the majority disagree that GIS is too difficult to learn, rather they want access to local GIS data and training in how to use the software.

Conclusion

This study set out to determine the status of the teaching of GIS in secondary schools in South Africa with respect to teacher skills and available resources. Reviewing the literature before the survey was set up, gave insight as to what was happening with GIS in secondary education both globally and locally. Results were obtained through an online survey with 112 teachers to determine teacher GIS skills level and resources and their perceptions of teaching GIS. These results were then cross-referenced with those from interviews of a sample of 9 teachers with similar demographics to those of the online sample group. A further aim of the study was to evaluate whether FOSS4G, namely open-source software (QGIS) and open data (OSM) would be effective teaching interventions in South African schools. FOSS4G was selected for the study for its ease of use, no cost implications and to avoid promoting a proprietary product. The qualitative research exposed teachers to OSM (OpenStreetMap) lessons and they were asked to evaluate if introducing practical, hands-on GIS lessons with FOSS4G would help with the understanding of GIS concepts, spatial skills and what aspects of the curriculum could be taught with GIS.

This research provided an opportunity to advance the understanding of how teachers' attitudes toward teaching GIS could be changed by using easy-to-acquire local data (OSM) and easily accessible GIS software (QGIS). The results show that the majority (91%) of the respondents agree that teachers have a negative attitude towards GIS. However, although the majority of teachers expressed a willingness to improve their GIS skills, 96% of participants attribute teachers' lack of competence in using GIS software as a key reason that GIS may not be used frequently in Geography lessons. The perceived usefulness of GIS, and school support for it, are important factors in influencing teachers' adoption of GIS (Lay *et al.,* 2013). The same was found to be true in this study. An overwhelming majority (95%) of the teachers agree that there are many benefits to using GIS in the classroom, which bodes well for changing negative attitudes towards GIS. When results were compared across survey questions and with the interview transcripts, it was the time constraints of teachers and the lack of easily accessible, user-friendly and simplified GIS software and access to local data and practical student courses that were highlighted.

There is limited local research on the use of OSM data with FOSS tools as a means to teach GIS in the classroom. Other studies in South Africa have used ESRI's Funda Lula (Mzuza & Van Der Westhuizen, 2019), Geomatica (Eksteen *et al.,* 2012; Fleming, 2013), IGIST (Fleischmann, 2017), ArcGIS online (ESRI, 2020) and QGIS (Mzuza & Van Der Westhuizen, 2019). Results for this study showed that only 50% of the respondents had heard of OSM and 6% indicated that they have possibly heard of the term. The feedback from the participants interviewed was very positive when they were asked if they would use OSM as a teaching tool. As the current political climate is looking into decolonising the curriculum, having access to local data, maps of local schools and local communities to use in the classroom is not only attractive but essential. OSM enables teachers to create their own material and makes it real for their pupils and learners as they can recognise their own 'place in space'.

South Africa is also one of the few curricula that includes geoprocessing in the Geography syllabus (Kerski *et al.,* 2013; DBE, 2018). However this is very difficult to teach if only a minority (21%) of the respondents teach practical GIS lessons frequently (more than once a month). What is also concerning is that a significant number of respondents do not teach the geoprocessing elements of spatial analysis, data integration and spatial queries in the curriculum. Results show that only 6% of respondents see themselves as GIS experts. The lack of teacher expertise may be another reason why these geoprocessing concepts are not taught as they are complex and only fully understood if applied practically.

However, findings in this study show that teachers have a very positive attitude and willingness to attend future GIS courses. An overwhelming majority see many benefits to teaching GIS in the classroom and are eager to learn more. Time constraints, curriculum pressures and a lack of know-how are the biggest hurdles to teaching practical GIS lessons. Surprisingly, access to hardware, GIS software and Internet connectivity were not seen as hurdles by the majority of respondents, although all the teacher's interview from schools in rural communities indicated power supply as their biggest concern to teaching GIS practical lessons.

6.1 Recommendations for the way forward

Recently, researchers have shown an interest in GIS as a tool to teach the curriculum. Degirmenci (2018) and Digan (2019) suggest a platform where teachers can collaborate and partner with one another and share GIS best practice. Participants in both the survey and interviews mentioned the need for a sharing platform for GIS resources for teachers. The sharing of GIS resources on the SAGTA website: https://sagta.org.za/ in South Africa is a recommendation of this research (Southern African Geography Teachers' Association). The support of the GIS industry in South Africa, such as GISSA (GIS Society of South Africa), can also play a role in linking GIS professionals to schools so they can come speak to their classes. It would be interesting to assess the effects of these guest visits on pupils/learners trying to use GIS tools on their own in a pre- and post-survey with teachers in future research. Another recommendation for future research is to further test the effectiveness of online teaching opportunities using FOSS4G tools on pupils/ learners from a range of schools and comparing across provinces as a follow up study.

More research in this area needs to be done as the spread of GIS in education is proceeding slowly (Anunti *et al.,* 2020). There was a flurry of excitement of the potential of GIS in education when it was first introduced into the curriculum in 2010 and there has not been much research done since. Many authors concur that further research is required, especially local research, and that there is a lack of published research on how best GIS can be implemented in schools (Wilmot & Dube, 2016; Tate & Jarvis, 2017; Healy & Walshe, 2019; Zondi & Tarisayi, 2020). The researcher agrees with the conclusions of Collins and Mitchell (2019) in that there is a need to create pockets of GIS excellence in some schools and create general awareness and excitement about the potential of GIS. This research has hopefully made a start with this process of creating an awareness as the interviewees definitely expressed excitement about FOSS4G and OSM potential. Here lies an accessible and affordable opportunity for educators to help engage their pupils and learners and promote the subject of Geography by teaching GIS in the classroom.

6.2 Limitations of this study

A limitation of this study is that only the opinions of the teachers were taken into consideration and not those of the pupils. It would have been very valuable to interview pupils and learners in a pre- and post-survey. Another limitation was that 56% of the respondents from the online survey and 90% of the teachers interviewed came from very resourced schools. Furthermore, the minority (14%) of the respondents who answered the online survey and participants interviewed (22%) taught at schools servicing rural communities. Although there is representation nationally, there is also a bias to Gauteng and KwaZulu-Natal, although this is representative of the population distribution of South Africa. What is now needed is a cross-national study involving more schools to determine if comprehensive teacher training is what is required to make GIS practical lessons more effective.

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Appendices

Appendix A: Consent letter

School of Geography, Archaeology and Environmental Studies

Private Bag 3, Wits 2050, South Africa Enquiries: **GEOGRAPHY:** TEL: +27 11 717-6503 • FAX: +27 086 651 6366
ARCHAEOLOGY: TEL: +27 11 717-6045 • FAX: +27 086 651 6366
http://www.wits.ac.za/geography/

WITS UNIVERSITY

October 2019

Please complete this consent form and return to Bridget Fleming 8903577T@students.wits.ac.za.

Title of project: The status of GIS teaching in South African secondary schools including an evaluation of Free and Open Source Software for Geospatial (FOSS4G) using QGIS software and OpenStreetMap (OSM) data as teaching interventions

Bridget Fleming
(Researcher)

Consent:

I ____agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. Please tick the relevant options below.

I agree that my participation will remain anonymous	YES	NO
I agree that the researcher may use anonymous quotes in her research report	YES	NO
I agree that the interview will be audio recorded	YES	NO
I agree that the information I provide may be used anonymously by other researchers following this project.	YES	NO

____
(Signature)

____
(Name of participant)

____
(Date)

Researcher: Bridget Fleming Tel: +2782 775 7072 Email: 8903577T@students.wits.ac.za
Supervisor: Dr. Mary Evans Tel: +2711 717 6521 Email: mary.evans@wits.ac.za

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Fleming

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/09/09**
PROJECT TITLE	The status of GIS teaching in South Africa secondary schools including an evaluation of Free and Open Source Software for Geospatial (FOSS4G) using QGIS software and OpenStreetMap (OSM) data as teaching interventions
INVESTIGATOR(S)	Mrs B Fleming
SCHOOL/DEPARTMENT	Geography, Archaeology and Environmental Studies/
DATE CONSIDERED	13 September 2019
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	21 October 2022

DATE 22 October 2019 **CHAIRPERSON** (Professor J Knight)

cc: Supervisor : Dr M Evans

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature ______________________ ____/____/____ Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

The status of GIS teaching in South African secondary schools.

Dear Geography teacher

I am doing my Masters of Science by research at Wits University and I invite you to take part in this survey which will take approximately 15 minutes. There are a maximum of 31 questions, split into three parts. This survey is for my Masters dissertation which investigates the status of GIS teaching in South African secondary schools with respect to teacher skills and resources available. Furthermore, to evaluate whether FOSS4G, namely open source software (QGIS) and open data (OSM) would be effective teacher interventions in South African schools.

The submission of this survey acts as consent to participate in this research project. All participation in this study is voluntary and refusal to participate will involve no penalties. You will not receive any direct benefits from participating in this study and may withdraw at any point. You are not required to answer all questions related to the survey and if you experience discomfort the survey may be stopped and postponed to another time. The surveys will remain anonymous, will not be disclosed to anyone and will be kept securely. All data collected will be stored securely in a password protected file on a private computer.

The analysis will be completely confidential and anonymous as I will not be asking for your name or any identifying information. The information you give will be held securely and not disclosed to anyone else. If you have any questions afterwards, feel free to contact me. This study will be written up as a research report. If you wish to receive a summary of this report, I will be happy to send it to you.

Kind regards
Bridget Fleming

Researcher: Bridget Fleming Tel: +2782 775 7072 Email: 8903577T@students.wits.ac.za
Supervisor: Dr. Mary Evans Tel: +2711 717 6521 Email: mary.evans@wits.ac.za

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WITS UNIVERSITY

Part A: How is GIS taught in the Geography classroom.

1. Describe the school that you currently teach in?

Mark only one oval.

	1	2	3	4	5	
Under resourced	◯	◯	◯	◯	◯	very well resourced

2. What type of school do you teach in?

Check all that apply.

	Servicing a rural community	Servicing an urban community
Government	☐	☐
Private	☐	☐

3. **What province is your school located in?**
Mark only one oval.

- Gauteng
- KZN
- Limpopo
- Mpumalanga
- North West
- Free State
- North Cape
- Eastern Cape
- Western Cape

4. **Which examination board curriculum do you follow?**
Check all that apply.

- Department of Basic Education (DBE)
- Independent Examination Board (IEB)
- Cambridge
- International Baccalaureate (IB)
- Other: ______________________

5. **How many teachers teach Geography at your school?**
Mark only one oval.

- 1
- 2
- 3
- 4
- > 5

6. **What percentage of pupils in grade 10 to 12 take Geography at your school?**
Check all that apply.

	< 20 %	21 to 40 %	41 to 60 %	61 to 80 %	> 80 %
Grade 10					
Grade 11					
Grade 12					

7. **Your gender is ...**
Mark only one oval.

- Female
- Male
- Prefer not to say
- Other: ______________________

8. **Your age is ...**
Mark only one oval.

- 20 - 29 years
- 30 - 39 years
- 40 - 49 years
- 50 - 59 years
- 60 - 64 years
- > 65 years
- Prefer not to say

9. **How many years have you been teaching secondary school Geography?**
Mark only one oval.

- 2 - 5 years
- 6 - 10 years
- 11 - 20 years
- 21 - 30 years
- > 31 years

10. **Rate your GIS expertise.**
Mark only one oval.

	1	2	3	4	5	
Beginner						Expert

11. **What GIS courses have you attended?**
Check all that apply.

- I studied GIS in my undergraduate course
- I completed an online GIS course
- I have attended a GIS short course (SAGTA/ Kartoza/ ESRI/ University/ other service provider)
- My district supervisor (DBE) cluster (IEB) arranged training/ workshop
- Other in service training
- I am self-taught
- I studied GIS at a post graduate level
- I have not attended any GIS training

12. **How frequently do your pupils use IT (desktop computers, laptops, tablets, phones) in the Geography classroom?**
Mark only one oval.

- They don't use IT
- They use IT very rarely
- They use IT often
- They use IT in every lesson

13. **When do you teach these GIS concepts in the curriculum?**
Check all that apply.

	GET phase (grade 7 to 9)	Grade 10	Grade 11	Grade 12	Never
What is a GIS	☐	☐	☐	☐	☐
Remote sensing	☐	☐	☐	☐	☐
Spatial data (points, lines, polygons)	☐	☐	☐	☐	☐
Spatial and attribute data	☐	☐	☐	☐	☐
Raster and vector data	☐	☐	☐	☐	☐
How data is captured into a GIS	☐	☐	☐	☐	☐
Spatial, spectral and temporal resolution	☐	☐	☐	☐	☐
Data standardisation, sharing and security	☐	☐	☐	☐	☐
Buffering	☐	☐	☐	☐	☐
Spatial query	☐	☐	☐	☐	☐
Data integration	☐	☐	☐	☐	☐
Statistical analysis	☐	☐	☐	☐	☐
Case study: GIS in the private and public sector	☐	☐	☐	☐	☐

14. **What techniques have you used to digitise spatial data?**
Check all that apply.

- ☐ Traced an aerial photograph or map (paper GIS task)
- ☐ digitising in Google Earth
- ☐ digitising in OpenStreetMap
- ☐ digitising in ArcView/ ArcGIS
- ☐ digitising in QGIS
- ☐ digitising using other GIS software

15. **How often are GIS practical (hands-on) lessons taught in your school.**
Mark only one oval.

	1	2	3	
Seldom (< one lesson a year)	◯	◯	◯	Frequently (once a month or more)

16. **Which part of the Geography curriculum have you used GIS to help teach? For example, you discuss how meteorologists track tropical cyclones using GIS (Physical Geography).**
Check all that apply.

- ☐ Map skills
- ☐ Physical Geography
- ☐ Human Geography
- ☐ Research projects and One Research Tasks (ORTs)
- ☐ Case studies
- ☐ I haven't used GIS to teach geographic concepts yet but I am interested to learn more
- ☐ I only teach GIS theory
- ☐ I don't use GIS

17. **Rate your level of interest in using GIS to help you teach the Geography curriculum.**

Mark only one oval.

	1	2	3	4	5	
Very interested	◯	◯	◯	◯	◯	Not interested

Part B: GIS resources available to teachers.

18. **What resources do you use to teach GIS?**

Check all that apply.

	Frequently/ mostly	When I can/ seldom	Never
Textbooks	☐	☐	☐
Class notes	☐	☐	☐
Digital presentations	☐	☐	☐
YouTube/ videos	☐	☐	☐
You demonstrate on your computer and project	☐	☐	☐
Invited guest speakers	☐	☐	☐
IT lab/ computer room	☐	☐	☐
Class laptops/ pupils bring their devices	☐	☐	☐
Cell phones	☐	☐	☐

19. **What computer hardware is available to you?**

Check all that apply.

- ☐ I have my own laptop
- ☐ I have the use of a computer in the Geography classroom
- ☐ I have the use of a computer but not in the Geography classroom
- ☐ I have the use of the IT lab/ computer room
- ☐ I do not have the use of a laptop or a computer

20. **What GIS software have you used?**

Check all that apply.

- ☐ Google Earth/ Google Maps
- ☐ Arcview/ ArcGIS (desktop or online)
- ☐ QGIS
- ☐ ESRI Story Maps/ OS Map Stories
- ☐ IGIST
- ☐ Funda Lula
- ☐ Geomatica Maptrix
- ☐ Other: ____________________

21. **What existing GIS resources would you like access to?**
Check all that apply.

- [ ] Hardware
- [ ] Software
- [ ] Data (Topographic vector layers and raster imagery)
- [ ] Notes and lessons (GIS theory)
- [ ] Courses (GIS practical)
- [ ] Other: ____________________

22. **What resources would you like to have developed for you to teach GIS?**

____
____
____
____
____

23. **Rate the WiFi connectivity that is available at your school.**
Mark only one oval.

	1	2	3	4	5	
None	◯	◯	◯	◯	◯	High speed broadband

24. **If you rely on the use of the IT lab/ computer room at your school, how accessible is this facility to you?**
Mark only one oval.

- ◯ I can never get to use it
- ◯ I can access it but it is difficult to book a slot for Geography
- ◯ It is always available to me
- ◯ I don't rely on the use of the IT lab

25. **What would make GIS more accessible to you in your classroom?**
Check all that apply.

- [ ] Better access to hardware (computers, laptops and tablets)
- [ ] Better WiFi connectivity to use online GIS services
- [ ] Cheaper or free software
- [ ] Training in the use of GIS software
- [ ] Access to pre-designed GIS lessons
- [ ] Access to local GIS data (topographic vector layers of your local area)
- [ ] Other: ____________________

Part C: Teacher reflection

26. **Have you heard of OpenStreetMap?**
Mark only one oval.

- Yes
- No
- Maybe

27. **Are you interested in up-skilling in GIS?**
Mark only one oval.

- Yes
- No
- I'm interested but don't have the time
- I'm interested but don't have the budget

28. **Are you interested in using GIS to produce your own maps for assessments?**
Mark only one oval.

- Yes
- No

29. **Why do you think GIS is not used more frequently in Geography lessons?**
Check all that apply.

	Agree	Disagree
Teachers are not competent at using GIS software	☐	☐
There is a lack of sufficient hardware and software	☐	☐
There is a lack of classroom environments suitable for the use of GIS	☐	☐
Teachers have a negative attitude toward GIS	☐	☐
It is too difficult to learn	☐	☐

30. **Why do you think GIS should be used in Geography lessons.**
Check all that apply.

	strongly agree	agree	impartial	disagree	strongly disagree
GIS allows for the comparison of geographic data	☐	☐	☐	☐	☐
GIS helps student to visualise geographic data	☐	☐	☐	☐	☐
GIS can be used to help explain geographic concepts	☐	☐	☐	☐	☐
GIS allows for experimental learning	☐	☐	☐	☐	☐
GIS facilitates the research enquiry process	☐	☐	☐	☐	☐
GIS allows for student-centred teaching	☐	☐	☐	☐	☐
GIS is a vital 21st century learning skill and helps student think critically	☐	☐	☐	☐	☐

Teacher interviews

Dear Geography teacher

I am doing my Masters of Science by research at Wits University and I invite you to take part in this interview. This interview forms part of my Masters dissertation which investigates the status of GIS teaching in South African secondary schools with respect to teacher skills and resources available. Furthermore, to evaluate whether FOSS4G, namely open source software (QGIS) and open data (OSM) would be effective teacher interventions in South African schools.

All participation in this interview is voluntary and refusal to participate will involve no penalties. You will not receive any direct benefits from participating in this study and may withdraw at any point. You are not required to answer all questions related to the interview and if you experience discomfort the survey may be stopped and postponed to another time. The interview will remain anonymous, will not be disclosed to anyone and will be kept securely. All data collected will be stored securely in a password protected file on a private computer.

The analysis will be completely confidential and anonymous as I will not be asking for your name or any identifying information. The information you give will be held securely and not disclosed to anyone else. If you have any questions afterwards, feel free to contact me. This study will be written up as a research report. If you wish to receive a summary of this report, I will be happy to send it to you.

Kind regards
Bridget Fleming

Researcher: Bridget Fleming Tel: +2782 775 7072 Email: 8903577T@students.wits.ac.za
Supervisor: Dr Mary Evans Tel: +2711 717 6521 Email: mary.evans@wits.ac.za

School of Geography, Archaeology and Environmental Studies
Private Bag 3, Wits 2050, South Africa Enquiries: **GEOGRAPHY:** TEL: +27 11 717-6503 • FAX: +27 086 651 6366
ARCHAEOLOGY: TEL: +27 11 717-6045 • FAX: +27 086 651 6366
http://www.wits.ac.za/geography/
WITS UNIVERSITY

1. **Date**

   Example: December 15, 2012

2. **Time**

   Example: 8:30 AM

3. **Location**

4. **What is the biggest advantage of using GIS in the Geography classroom?**

5. **What are the biggest hurdles to using GIS in the Geography classroom?**

6. **After observing how to download OSM local data of your school using QGIS software, how would you use this to teach GIS theory?**

7. **Could your pupils/learners use this for their own Geography research projects (DBE and IEB)/ ORTs (IEB) in grade 12?**

   Mark only one oval.

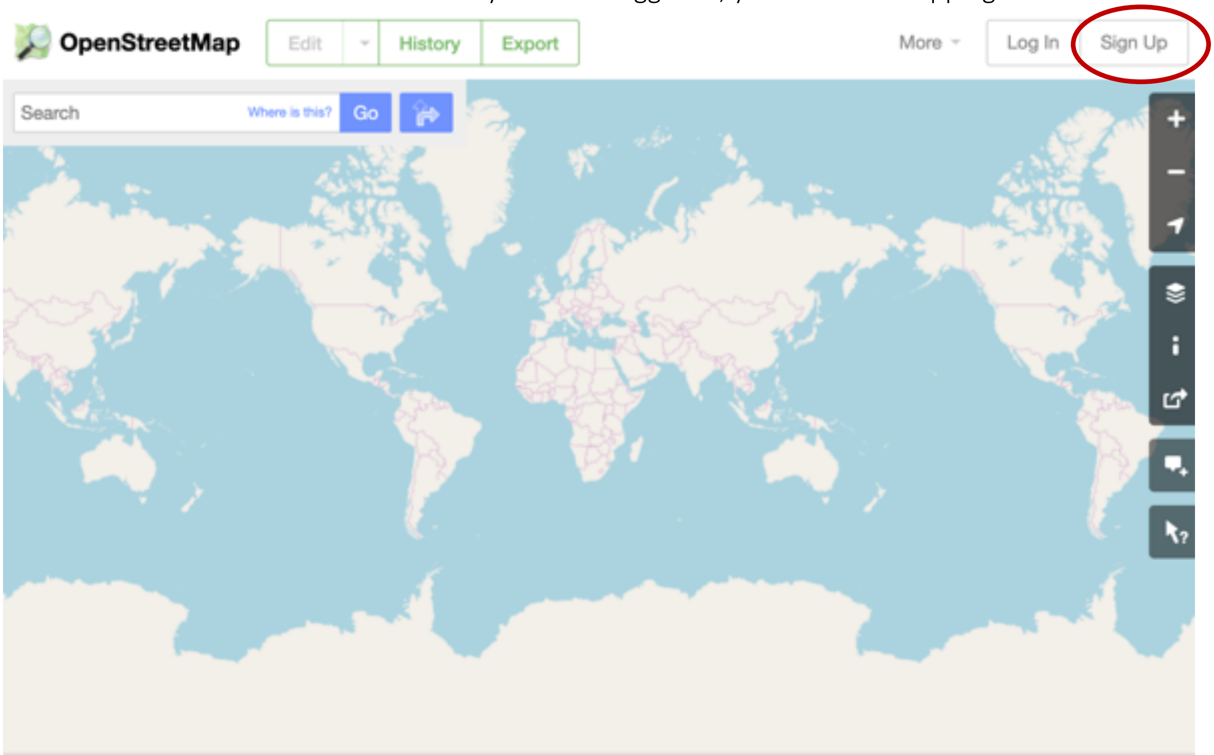
   - Yes
   - No
   - Maybe
   - Other: ____________________

8. **How else can QGIS and OSM be used in the Geography classroom to teach the curriculum?**

OSM Cheat Sheet – four easy steps to start mapping

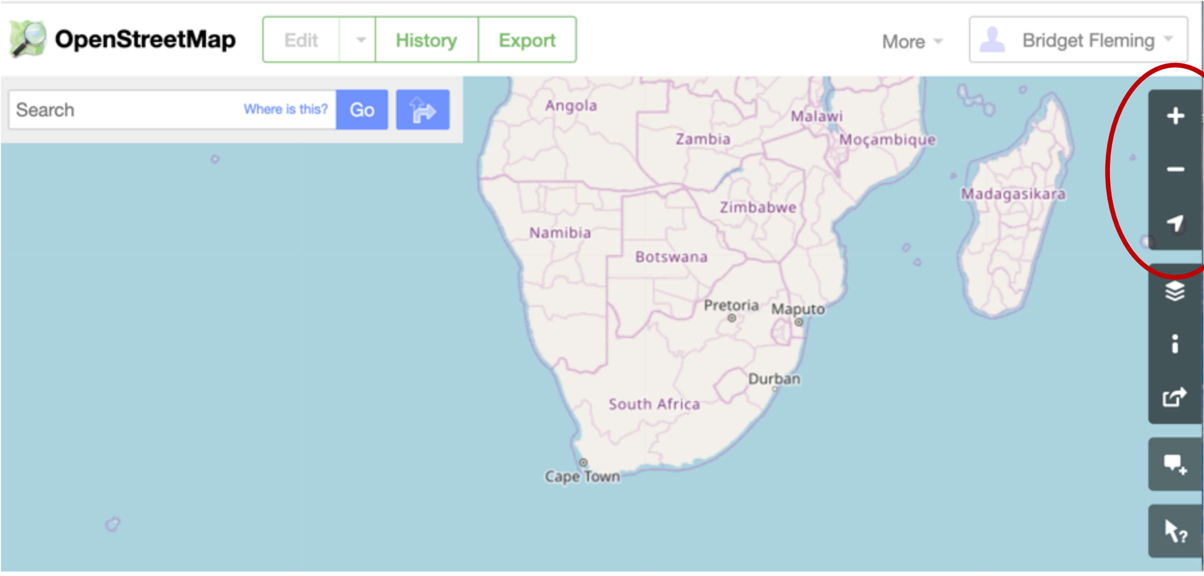
Step 1: Register on OSM OpenStreetMap website

- Go to https://www.openstreetmap.org
- Click on "Sign Up" if you have never logged in before. Keep your password safe and a confirmation mail will be sent to you. Once logged in, you can start mapping.



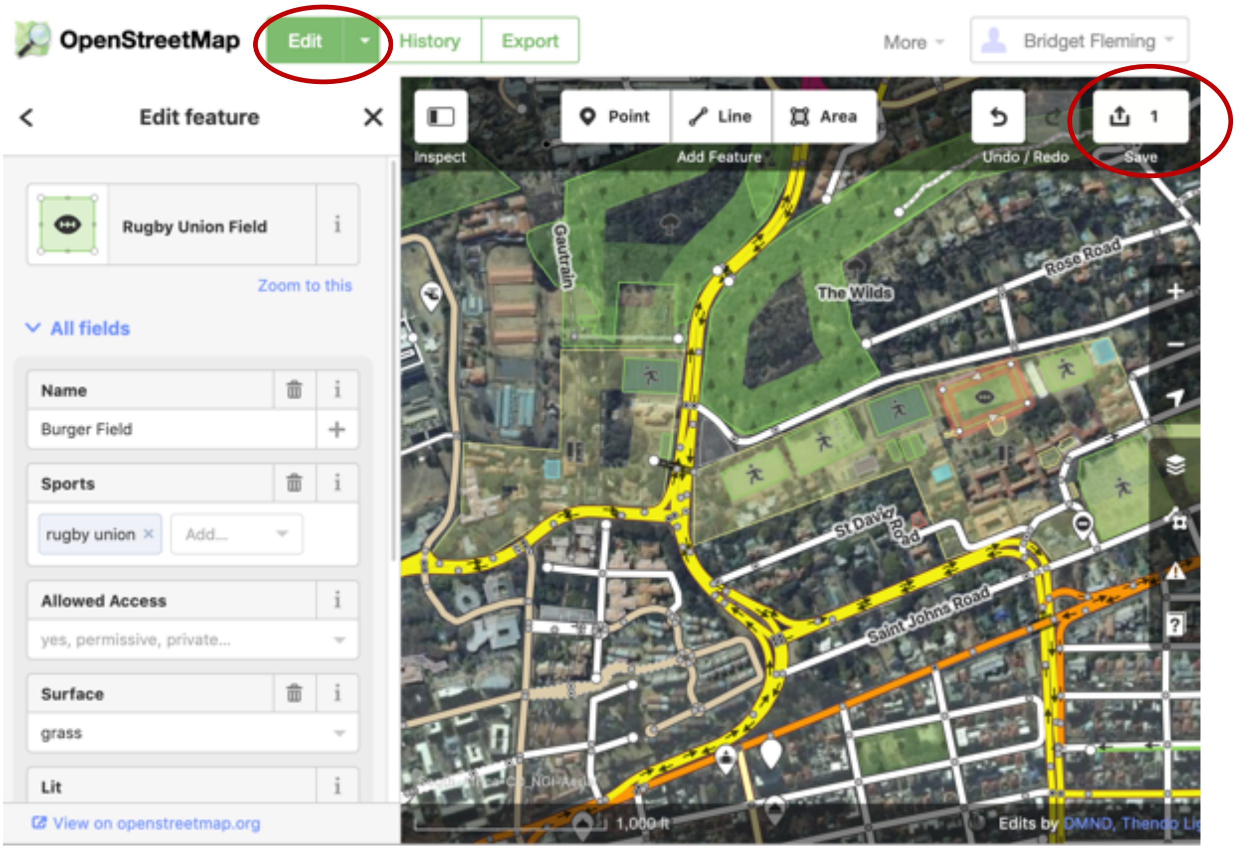
Step 2: Find the location you want to map

- Use the zoom in or out tool on the right or type in your location in "search" and click "Go".



Step 3: How to Edit

- Click on the “Edit” tool.
- Make your you have zoomed in sufficiently to digitise map features accurately.
- Decide if your map feature is a “Point”, a “Line” or an “Area”/Polygon. Click on the feature type and place the cross hairs on the feature you are mapping.



- “Left” click on your mouse or touch pad to make a point then move and click again to build up the feature, then “right” click to close a polygon or end a line. Right click again or press ‘q’ to make sure the corners are square. The option to “cut” or “delete” is also available when you “right” click.
- You then have the option to add “attribute data” to your newly digitised map feature. On the left you can add “fields” or attributes by clicking on the drop-down option. Populate as many fields as you can from what you can see in the photo or what you know about the feature. Above you can see the Name “Burger field”; Sports “rugby”; access is allowed and the surface is “grass”. You have the option to edit later once you have ‘ground-truthed’ the feature in real life.
- Don’t forget to save (top right) once you have mapped/digitised your map features. You must write a comment (‘commit message’) describing what you did each time you save.
- Once your data is saved, you can “Export” your data as an .osm file and load it into QGIS.

Step 4:

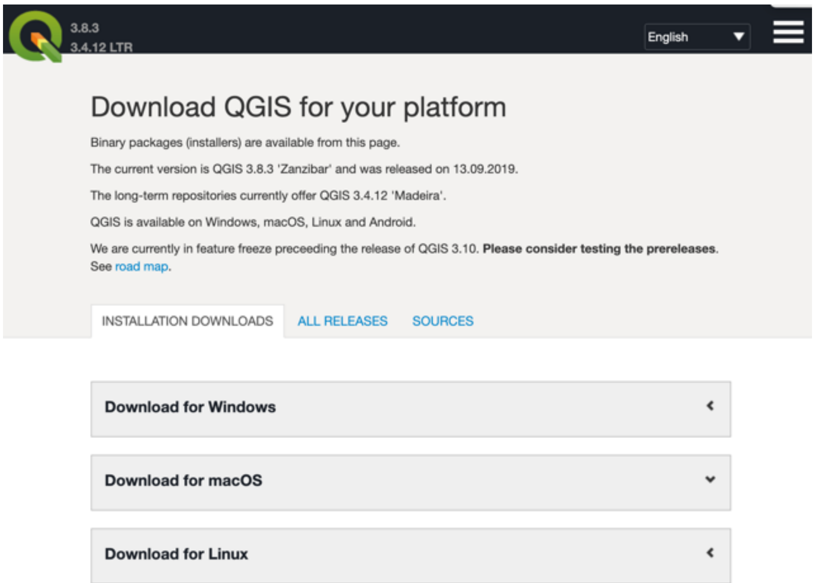
Watch this 10 min YouTube video
https://www.youtube.com/watch?v=Ir-3K0pjwOI

on how to map in OSM and why mapping is so important and can save lives.

Using OSM data for Geography Research Projects in QGIS in Five Easy Steps

Step 1: Download QGIS

- Go to https://qgis.org/en/site/forusers/download.html

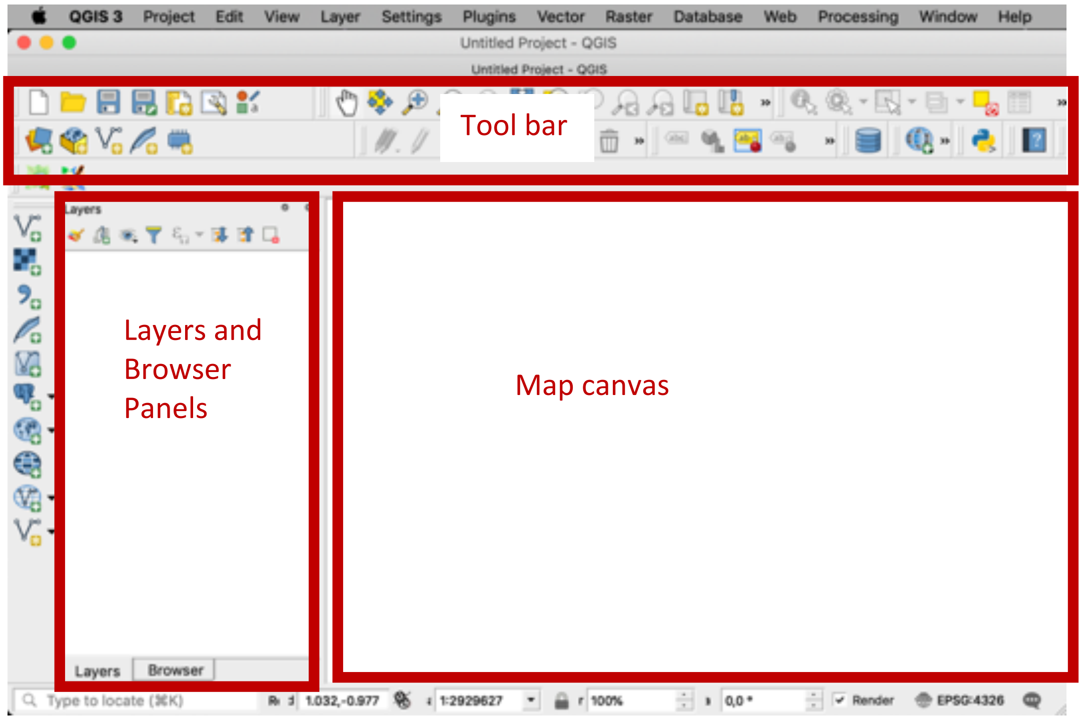


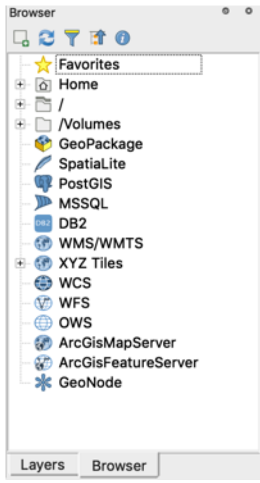
- For Windows your laptop/desktop is most likely 64 bit. Choose the stable long term release QGIS 3.4 Madeira.

- For Mac users, follow the instructions regarding installing Python first.
- QGIS is Open Source so there is no cost involved in purchasing the software.
- You do not need connectivity to use QGIS once the software is downloaded.

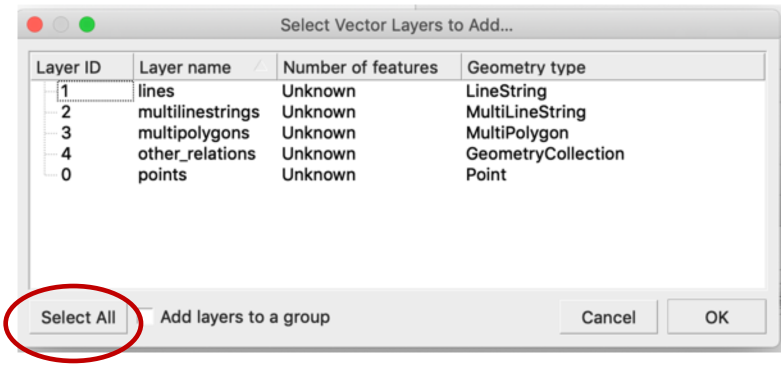
Step 2: Load your OSM data in QGIS as vector layers

- Use the "OSM cheat sheet" to digitise the data you need for your research project and export it.
- Open QGIS and note the layers and browser panels, map canvas and tool bar (see page two). If you don't have a layers or browser panel, right-click on a black space in the tool bar and a drop down window will appear. Find them and tick them to bring them up.

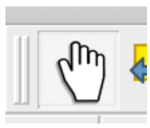




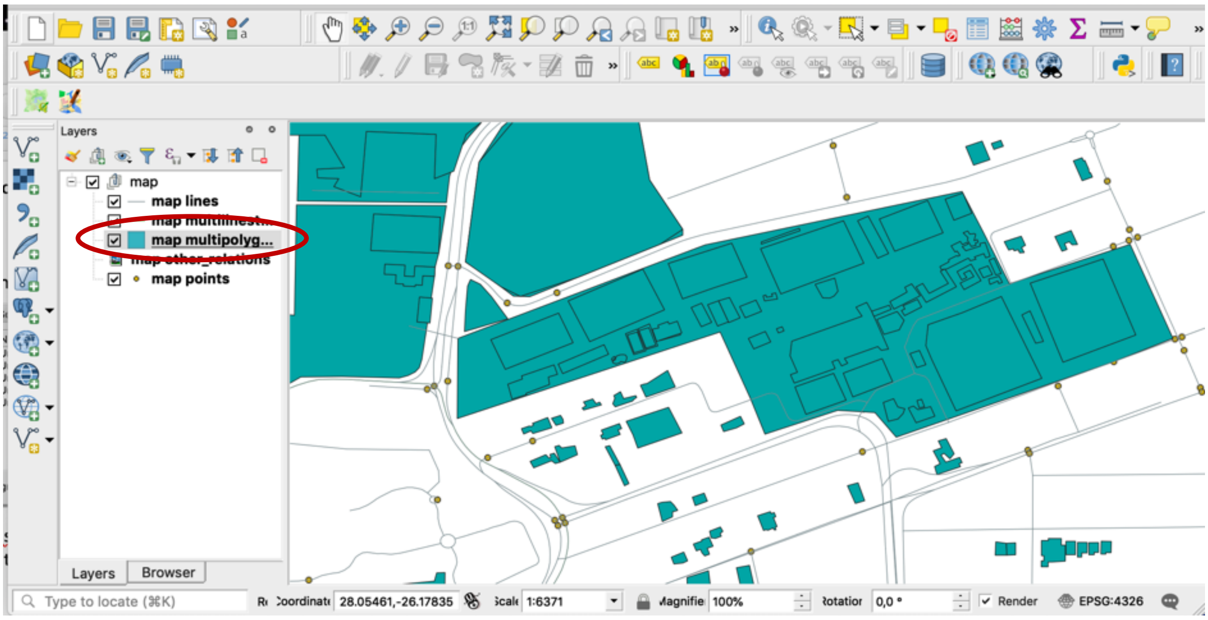
- Click on “Browser” and navigate to where you saved your map.osm data.
- Or click and drag your map.osm data file onto the map canvas.
- Click select all when the window below comes up.



- Your map data from osm will now be displayed in the map canvas and the vector layers will be listed in the layers panel, see page three.
- Use the “Pan” tool to position your map nicely on the map canvas.

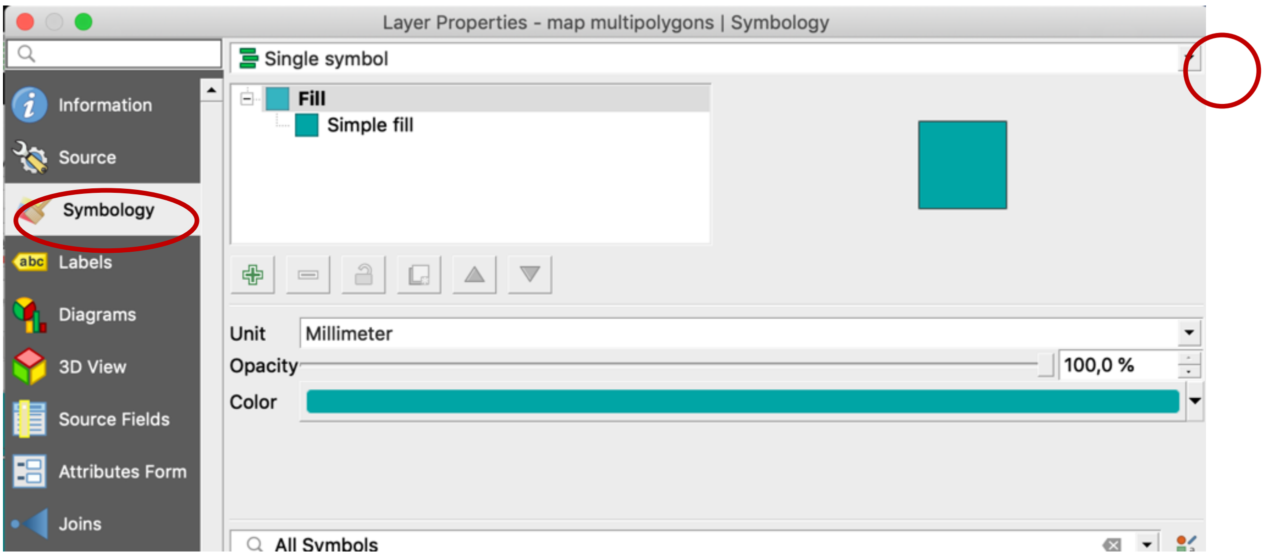


- **Always remember to save** your project in case there is load shedding:

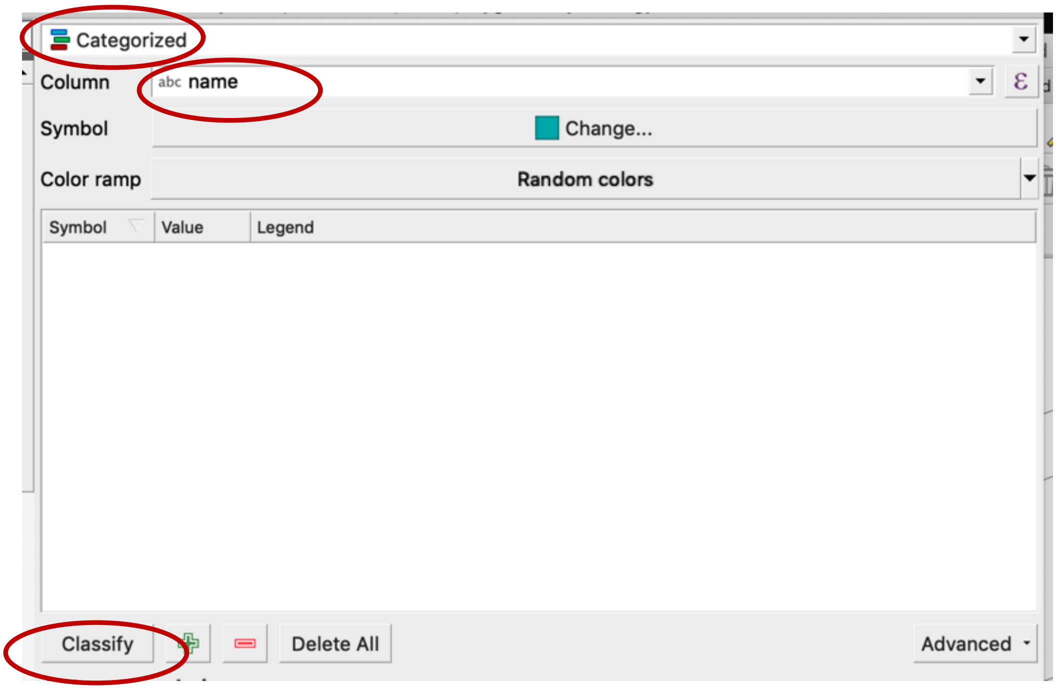


Step 3: Styling your data

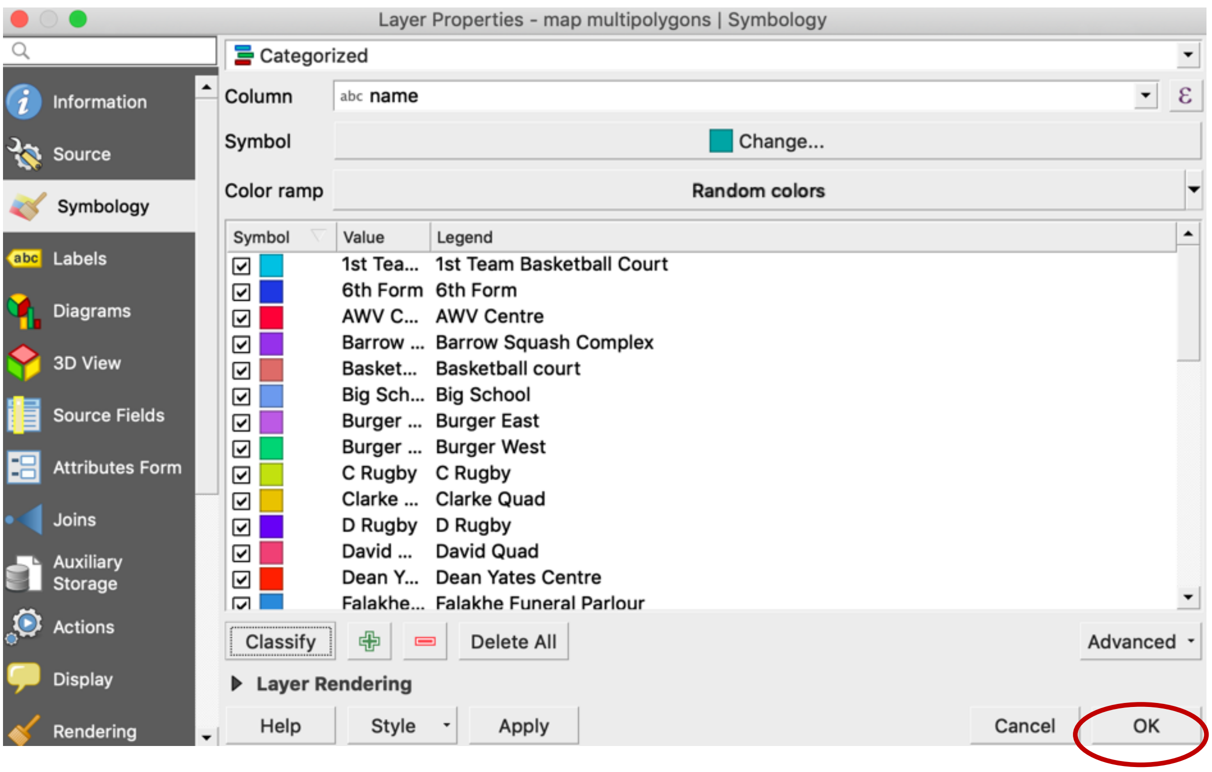
- Activate map mulipolygon layer by clicking on it, see above. Right-click and a list will appear. Find "properties" and this window will appear:



- Click on "Symbology".
- Then click on the drop down arrow next to "single symbol", see above.

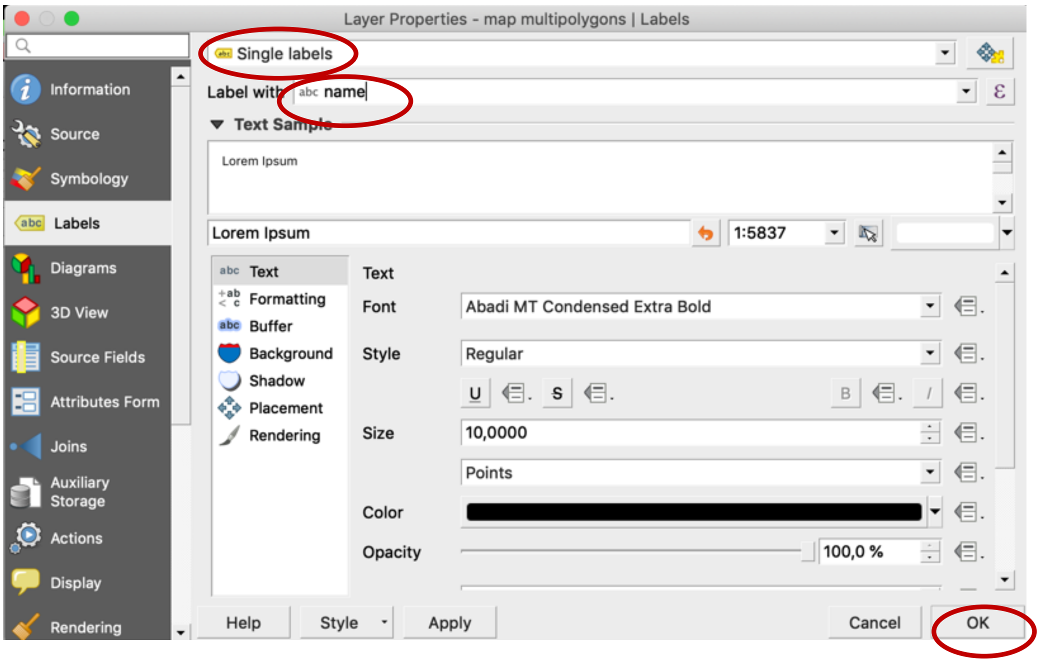


- Click “Categorize”.
- Under column click “name” as we want to categorize the map data by name.
- Keep the color ramp as “random colors/ colours”.
- Finally click “classify”, see above.
- Once it looks like the window below, click OK. See below:



- The map data for polygons will then be displayed and listed in the “layers” panel. See page five.

- You can restyle the roads/ map lines by activating that layer; right clicking; clicking "properties" and then "symbology". You can be creative and artistic with "styling" your map data.
- You can label your polygons by activating that layer; right clicking; clicking "properties" and then "labels".
- Then click "single labels"; label with "name" and click OK, see below:

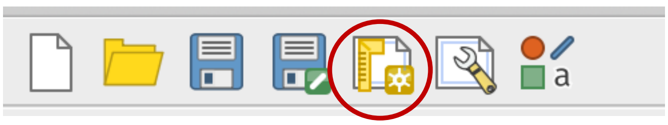


- The map data will then be labelled on the map canvas. See page 6.

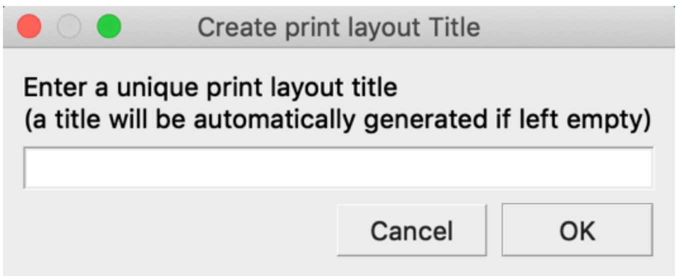
- You can remove layers by right clicking on them and clicking “remove layer”.

Step 4: Producing a map of your data

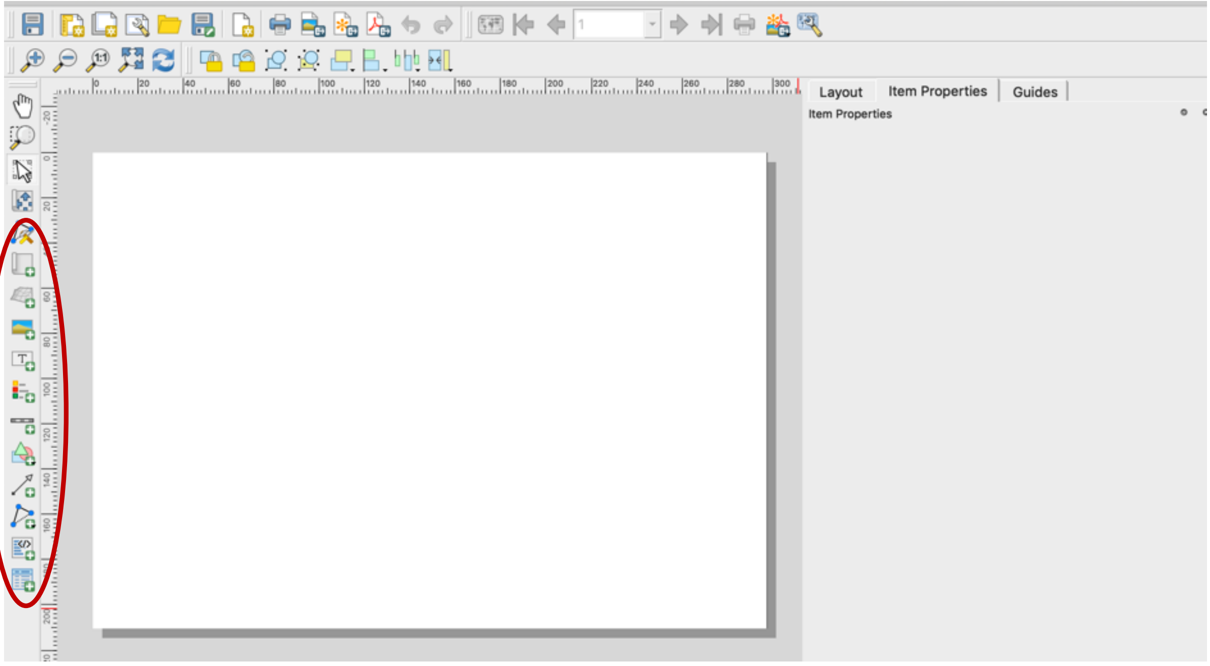
- Click on “New Print Layout” tool.



- Give your “print layout” a name:

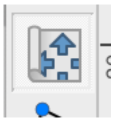


- Another window will appear. For Windows user you can toggle between the two windows at the bottom. For Mac users, you can drag between the two.
- A black page will appear on a new window, see page 7. You are now about to try your hand at cartography.
- A good map needs the following:
    - A heading
    - A north arrow
    - A legend/ key
    - A scale bar
    - A logo

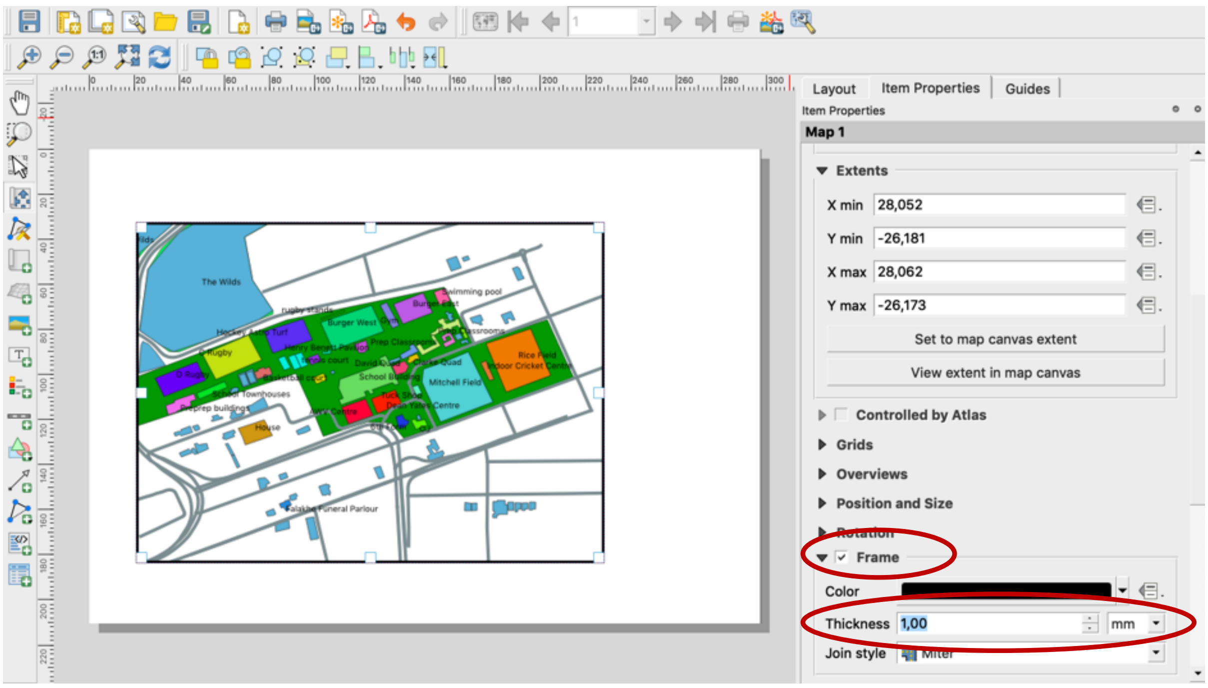


- The first map element to add is the map from QGIS. Click on the "add new map" tool. This can be found on the left hand side, see above.

- Cross hairs will appear. Click and drag where you want your map on the black canvas. Click on the "pan" toll to move any element later.
- Your map will then be displayed.
- You can move or zoom the map inside the map area by clicking on the "move item tool".

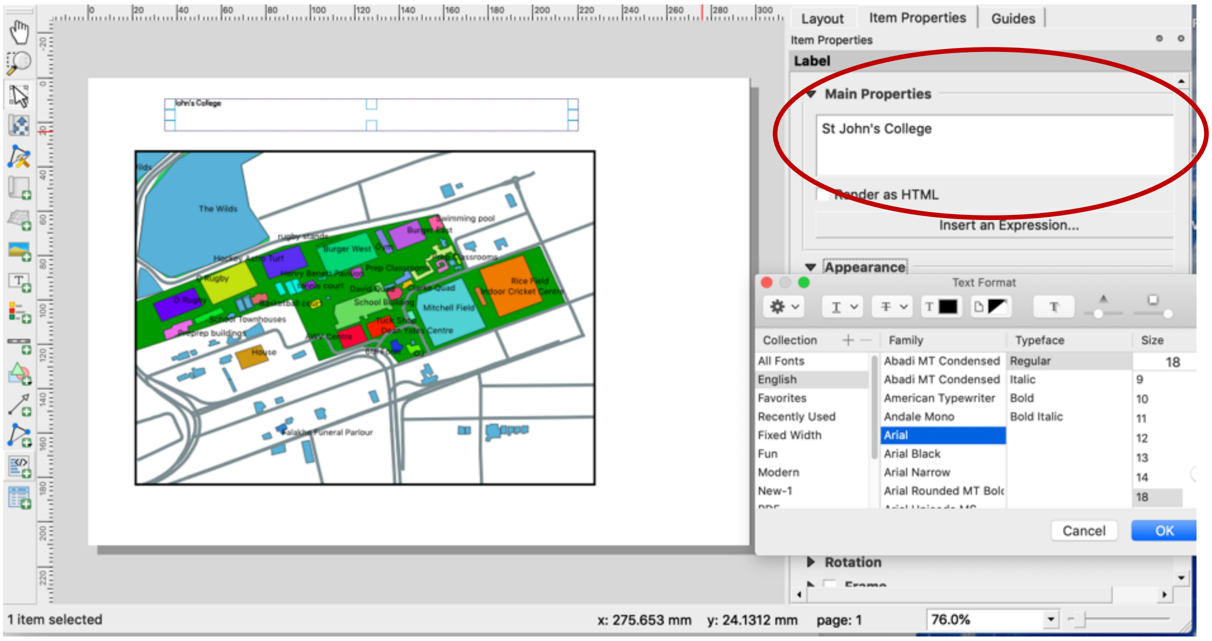


- You can add a frame by ticking frame and the thickness of the frame in the "item Properties" panel, see below:



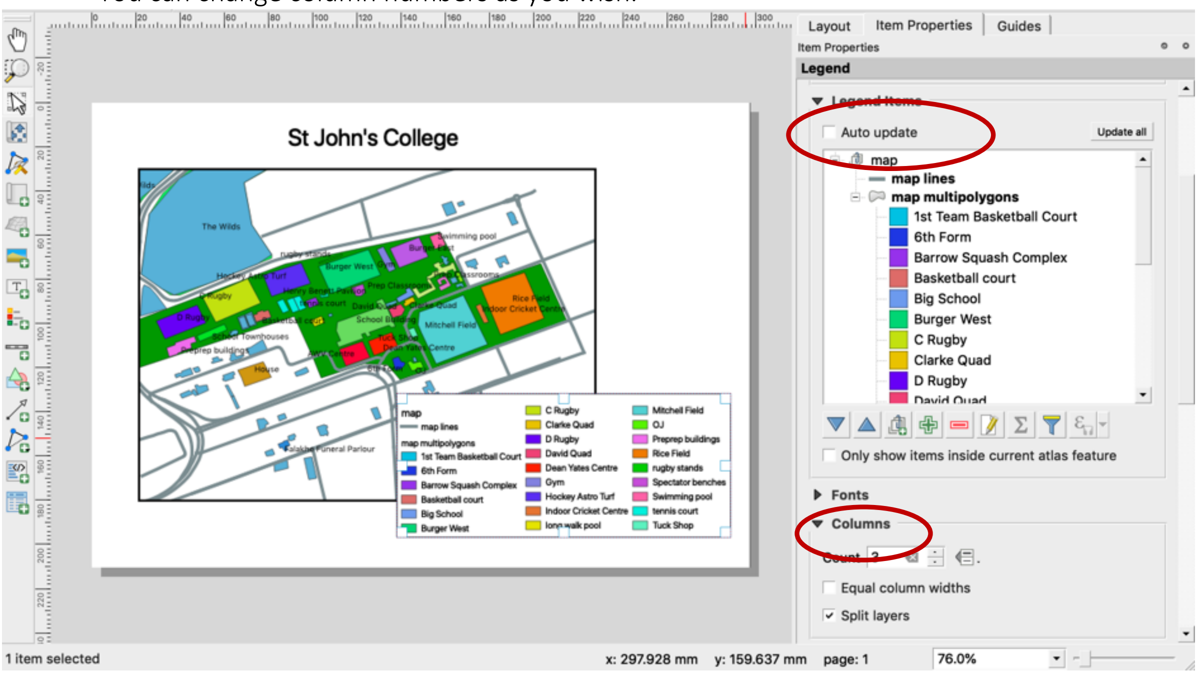
- If you make a mistake, click undo or on the item and delete on your keyboard.

- Add a heading by clicking on the “add new label” tool.
- Cross hairs will appear.
- Type in the heading under item properties, see below.
- Click on “Appearance” to change text type, size etc.

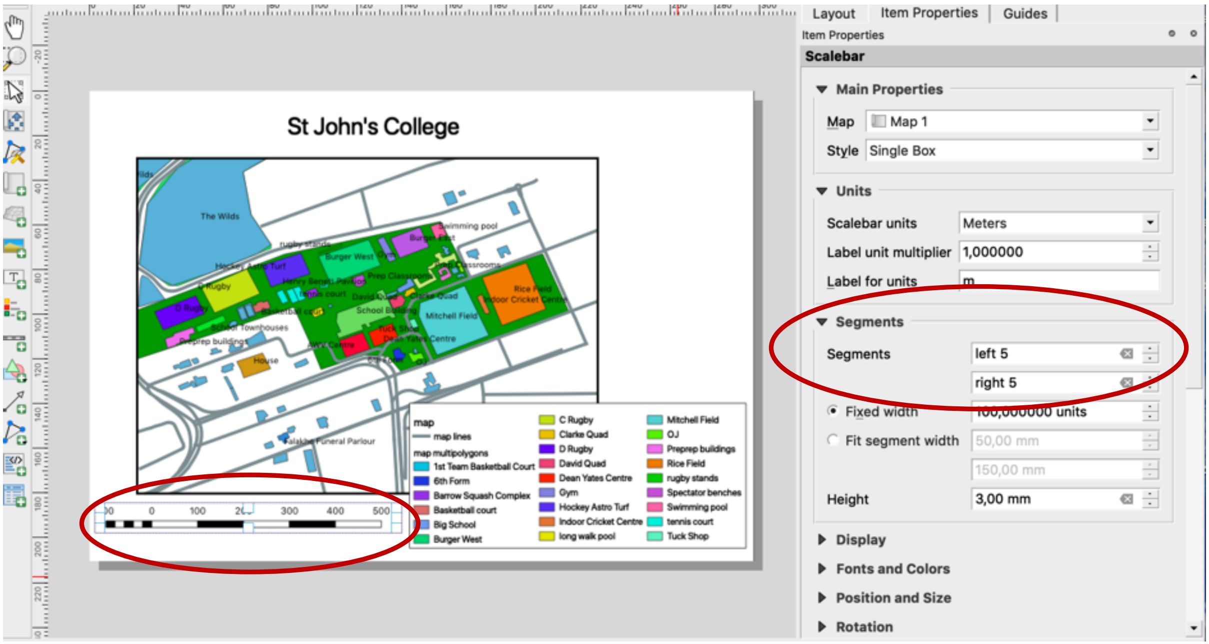


To add a legend click on Add legend tool.

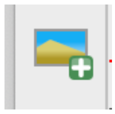
- Cross hairs will appear, place your legend on the map canvass.
- A long list will appear.
- Untick “Auto update”, click on the layer you want to remove and click the red minus sign, see blow.
- You can change column numbers as you wish.

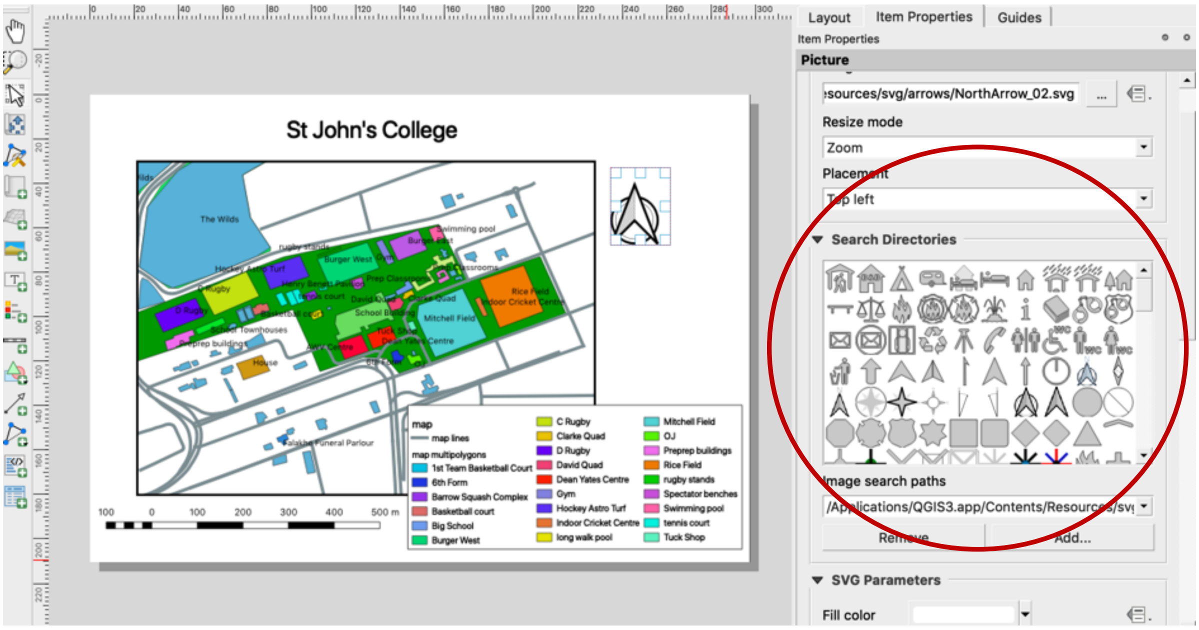


- To add a scale bar, click on the scale bar tool.
- You can add segments to the right and to the left of 0 m, see below:



- The best way to add a north arrow is to click on add a new picture tool.
- Click on Search Directories to select a north arrow symbol, see below: You can also source an image that you have saved and navigate to it using "Image Source".
- Using the same tool you can add a logo.





Step 5: Exporting your map

- Once you are happy with your map, you are ready to export it. You can export it either as an image, an SVG file or as a PDF.
- You are now a GIS practitioner and a cartographer! Go and share the GIS LOVE ...