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Teaching Geographic Information Systems (GIS) in South African High Schools in the Frances Baard District

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Abstract Geographic Information Systems (GIS) is an exciting development in Geography education locally and internationally. GIS has been part of the senior high school Geography curriculum for over a decade in South Africa. However, matric pass rates in the GIS section of Geography, which is examined in paper 2 of the national examinations, are low. This research was conducted to investigate the teaching methods used by teachers to teach GIS in high schools in the Frances Baard district, Northern Cape Province. The mixed method approach and the multiple-case study design were used for the study. Data from teachers were gathered using a questionnaire, interviews, and lesson observations. The questionnaire was completed by 50 teachers, and 10 teachers were interviewed and observed while teaching GIS topics. Results showed that most teachers used multiple teaching approaches, which were mainly teacher-centred. These included lecturing, explanation, questioning at the expense of learner-centred approaches that were fundamental for GIS instruction. These methods were used due to challenges that teachers faced in GIS teaching including a lack of physical resources to teach GIS, large classes, a lack of proper training, and time constraints. The question of how GIS should be taught in high schools has been a source of consternation among geography educators, more especially in developing countries such as South Africa, where some schools lack resources such as computers, GIS software, internet connectivity, and electricity connection. The utility and value of having GIS in the curriculum, such as promoting e-education generally, cannot be achieved if there is no systemic initiative to create appropriate environments and skills for teachers entrusted with teaching GIS. The current teaching approaches used fail to propel GIS to better learning and understanding by the learners. This is reflected by the ongoing low pass rate in the GIS section nationally. The study proposes a paradigm shift in the way GIS is being taught in high schools. Teachers should use teaching methods that are learner-centred. Students would then actively create knowledge through their own GIS experiences as a result of the learner-centred teaching methods. We argue that GIS topics should be taught in GIS laboratories, where learners are taught both theory and its practical application.

Keywords Geographic Information Systems (GIS), Pedagogical Approaches, TPACK

1. Introduction

Globally, the growth in Information and Communications Technology (ICT) has affected all aspects of life, and schools have not been immune from this influence [1]. GIS is a concept imbedded in geography. GIS stands for Geographic Information System, and it is a

system for storing, updating, analyzing, displaying, and manipulating spatial data-information about locations on the earth [2]. Its instruction is intended to impart knowledge and skills in accordance with national educational goals. The levels of assignments designed should prepare the learner for the future world of work, as well as an understanding of how to interact with the environment.

In many countries, the incorporation of GIS into the school Geography curriculum is viewed as necessary for the improvement of quality methodologies in the teaching and learning of the subject. Many countries like the United States of America (USA), Turkey, Japan, Finland, India, Canada, Serbia, Rwanda, Ghana and South Africa, to mention a few, have implemented GIS in high schools, and committed significant resources in programs that use ICT in education [3, 4]. When properly implemented, these initiatives have the potential to bring about significant ICT-based educational reform and, in particular, GIS-based teaching in Geography. This will help transform learners into active knowledge constructors [5]. [6, 7] comments that "an educated citizen in the year 2020 will be more valuable as an employee, because he or she will be able to produce more builders of theory, synthesizers, and inventors of strategy than one who manages facts".

Research has also confirmed that students who have the opportunity to use modern teaching and learning technology develop their geographic knowledge, skills, and attitudes more successfully [8]. Le Grange and Ontong [9] note that the introduction of GIS into the Geography curriculum in South African secondary schools was a step in the right direction. GIS is known around the world for promoting an inquiry-based learning (IBL) environment [5]. GIS, by its nature, enhances problem-based learning (PBL) and inquiry-based learning in the secondary school curriculum [4, 10]. Johansson [10] states that "problem-based learning (PBL) and inquiry-based learning are instructional methods which are based on constructivism and are challenging the customary methods used in secondary schools". Besides promoting PBL and inquiry-based skills in learners, GIS provides pedagogical benefits to the learners. Goodchild and Kemp [11] is of the view that GIS encourages learners to seek jobs in science and engineering. It is also argued that GIS motivates learners to learn Geography [4]. Komlenovic, Manic and Malinic [8] state that students are enabled to monitor and anticipate the origins, development, and implications of changes in geographic phenomena using GIS, and they can answer essential questions such as what, where, and why certain spatial phenomena appear on the globe the way they do.

The introduction of GIS in South African high schools has, however, not been matched by the creation of appropriate teaching environments, and skills to enable the value of GIS in schools to be achieved. The continued poor performance of learners in the GIS section in the matric examination is a cause for concern [12, 13]. This lack of a proper foundation in GIS is also reflected in the poor results in the GIS modules offered at universities. Students who take the GIS module, be they Bachelor of Education or Bachelor of Arts students, struggle with the GIS module. It is from this background that this research sought to examine the teaching methods used to teach GIS in high schools.

This paper sought an understanding of the teaching methods used by teachers to teach GIS topics in Geography in the Northern Cape Province high schools, in South Africa. Although some studies have been carried out on the challenges of teaching GIS, such as the inadequate training of teachers in GIS, there has been no research on how GIS is actually taught. This research, therefore, investigated how teachers taught this new concept in Geography in high schools in South Africa.

To achieve its goal, the study was guided by the following two research questions:

- What are the pedagogical approaches used by high school teachers to teach GIS?
- Why do high school teachers use these pedagogical approaches to teach GIS?

The objectives of this study were to:

- explore the pedagogical approaches used in teaching aspects of GIS; and
- examine the reasons why these particular pedagogical approaches are used to teach GIS.

2. Background

The teaching and implementation of GIS in high schools has a short history [4]. Countries such as the USA, Finland, Turkey, Japan just to name a few, are among some that have adopted GIS teaching in secondary schools [10]. In South Africa, GIS was introduced in the Geography curriculum a decade ago, and it is taught as a sub-section in the map work section. The National Curriculum Statement (NCS) first introduced GIS into Geography at school level in 2006. It is also mentioned in the new Curriculum and the Geography Policy Assessment Statement (CAPS) documents [14]. The CAPS document encourages the teaching of GIS concepts. The GIS section forms part of Geographical skills and techniques learners should acquire in Grades 10, 11 and 12. The CAPS document for Geography for grades 10-12 provides a detailed outline of the skills that must be taught in GIS classes. These skills include how remote sensing works, techniques for creating and using spatial reference data, spatial and spectral resolution, and how to manipulate data. Teachers are expected to both have these skills, as well as teach them.

GIS, as a tool for teaching some aspects of Geography, has the potential for PBL and IBL [3, 4]. GIS directs the teaching process towards students/learners. This allows them to get involved and acquire a higher level of functional knowledge [8].

According to Demirci and Karaburun [15], providing schools with many computers does not necessarily imply that educational goals of integrating technology into the curriculum have been met. Amidst the rapid advances and diffusion of ICT in the 1990, many studies from that time, and in the early 2000s, reported failures in various countries to integrate ICT into educational systems [4, 15]. Despite reports of a rise in the number of computers in schools, computers are still not widely used in many countries' classrooms. According to Watson [17], despite the fact that teachers own and use computers for administrative purposes, many of them never use computers in their classrooms. According to the findings of a survey conducted by [16], many teachers today use technology less than they did in the mid-1980s. According to Demirci and Karaburun [15], studies show that, simply providing technology to teachers and students in schools and classrooms, is insufficient to achieve educational goals, and ensure that technology contributes to learning and teaching. What is required is the effective integration of GIS into education.

The use of technology, and in particular GIS, is also hindered in many ways by teachers' limited time and resources to understand the complexities of a GIS software program like ArcMap. Regardless of the availability of computers and the software in schools, fewer schools in England use GIS [18]. Supplies of computers alone in schools will therefore, not guarantee the integration of GIS [15].

3. Literature Review

Teaching approach/pedagogical approach is a broader term than a teaching method. “Teaching approach is like the form or the way we teach or how we do it” [19]. There are numerous approaches that are used in the teaching and learning process and can be broadly divided into teacher centered [20] and learner-centered approaches [21, 22]. Learner-centred pedagogy aims to foster learner independence by putting learners in charge of their own learning. It involves learner-centred instruction that focuses on skills and practices that enable lifelong learning and independent problem-solving [23]. Numerous terms are associated with student-centred learning, including collaborative learning [24], flexible learning [25], experiential learning [26], learner-centred learning [23], and self-directed learning. In a teacher-centred pedagogical approach, it is the duty of the teacher to make sure that learning activities are planned and structured, and the teacher establishes the time and method for the completion of the tasks [20]. Teacher-centred pedagogies are modelled on an active teacher and a passive learner [20]. Furthermore, learner-centred pedagogy is frequently accompanied by a problem-based approach, in which problems are chosen to pique learners' interest and to focus on the needs of learners [27].

The type of activity we employ to teach is referred to as the teaching approach. It refers to a procedure within a method. The term method covers both strategy and techniques of teaching [19]. These teaching methods are also grouped into teacher-centred and learner-centred categories. Examples of teacher-centred teaching methods include: Lecturing method [28]; Discussion [27]; Questioning [28, 30]; Explaining method [29]. For these teacher-centred teaching methods to be effective, they depend very much on the teacher’s characteristics. For instance, the teacher’s ability to be clear, audible, use words that learners are familiar with, provide good explanations of concepts, and to ask relevant questions at the right stage of the lesson development is very essential. Learner-centred pedagogy, also known as student-centred pedagogy, includes teaching methods that shift the focus of instruction away from the teacher and towards the learners. These include teaching methods such as Discovery [31], Demonstration; [30], Fieldwork [32], and Project work [33].

For a teaching approach to be applicable and effective, it must be related to the learner's characteristics, as well as the type of learning it is intended to provide. However, there is need to re-differentiate the *centre* of this instructional debate between learner-centred and teacher-centred pedagogies. If the main actors (learner and teacher) are isolated, then we can pay attention to the action of the instruction itself. This results in a third type of instruction, known as learning-centred pedagogy, which has been described by [21] as creating learning-centred environments, which attempt to consider the concern between learning achievement and different learners’ needs. McCombs [21] notes that a learning-centred pedagogy is useful for predicting a learner’s motivation and level of learning attainment. This instructional pedagogy is also viewed by [34] as one that promotes learning based on consideration of students’ needs, strengths, weaknesses, and general competencies in a way that results in active student participation. Lessons taught in learning-centred environments are planned after considering the students’ experiences, as well as their prior knowledge of the subject [35].

The choice of teaching methods, therefore, depends very much on the overall goal, the choice of content, the situation (context of the school), the subject, and the learner’s conditions [36].

A comprehension of pedagogical content knowledge (PCK) is also critical to the teaching of any subject in the classroom. For the teacher to be effective in teaching GIS, they should have sound knowledge of GIS and pedagogical approaches used to teach that subject [37]. Knowledge of PCK, comprehension of subject matter specific knowledge, and pedagogy that teachers utilize on a daily basis, can be used to produce teaching materials for learners. What is typically taught directly in classes is content knowledge. Lack of that knowledge can negatively affect the teacher’s choice of teaching method to teach the subject. Gains in

pedagogical content understanding among teachers will lead to learning gains among students [38].

However, challenges such as "inadequate resources and limited exposure of students to GIS's practical uses" [3] have hampered GIS teaching. Only a small number of public schools have computers for students to utilize, and an even smaller percentage have the finance to purchase the software needed to effectively teach GIS [39]. Many perceive GIS as a volatile link between paper-based map study, and IT resources that are currently unavailable for instruction in the majority of South African schools. There is also a big gap between township and rural schools, and former model C schools in terms of physical resources availability. Most of the high schools in rural and township schools lack physical resources such as computer labs, data projectors, internet connections and smart boards etc. On the contrary, former model C schools can afford most, if not all, this equipment [40]. That being the case, the polarization of schools, which dates back to the years of apartheid, continues to affect the implementation and teaching of GIS in high schools. This has resulted in teachers failing to effectively integrate technology into their teaching of GIS. This necessitates an understanding of GIS teachers' knowledge of technology, pedagogy, and GIS content (TPACK), as well as their technological integration strategies and perceived barriers. TPACK describes how teachers integrate technology in the classroom [41].

As has been alluded to earlier, the selection of teaching methods to use when teaching any subject is beset by many barriers [3, 16]. A variety of barriers to technology integration in the classroom have been identified. Ertmer [42] classifies these barriers as external or internal. External barriers in his study include lack of equipment, unreliability of equipment, a lack of technical support, and other resource-related issues, whereas internal barriers include school and teacher-level factors such as beliefs about teaching and technology.

According to Demirc and Karaburun [15], studies have shown that teachers' lack of competence, lack of knowledge, lack of prior experience, and resistance to incorporating new technologies into their lessons, are the major barriers that influence the teaching methods that teachers use in the classroom when teaching [43]. When teachers lack the confidence to incorporate technology into their lessons, they tend to disregard that technology [44]. Other factors influencing teachers' decisions to use new technologies in the classroom include access to resources, the quality of software and hardware, ease of use, incentives to change, support available, collegiality in the school, and commitment to professional learning [45].

Several authors have argued that another factor that improves learner achievement is the reduction of class sizes [46]. Proponents of smaller classes, such as [47] and [48], believe that they provide for higher-quality learning opportunities, the development of teacher-learner relationships, more individualized and learner-centric training, increased teacher morale, and fewer student misbehaviors. In classes where the number of learners is small, teachers tend to use more learner-centred teaching approaches and promote more individualized teacher support for learning, than they do when classes are large. Learners also tend to outperform their peers in larger classroom settings [49]. According to literature, class size reduction should be done in concert with other measures to achieve the greatest impact [49]. A study of teaching methods, classroom management, and in-service training are examples of these. Simply reducing class sizes without having enough skilled teachers or reducing class sizes insufficiently to have a significant impact, makes no difference [49].

There is also an assumption that “all other things being equal, teachers with more experience are better teachers” [50]. However, a study by Irvine [51] indicates that the relationship between “total years of experience and teacher effectiveness, as measured by student achievement gains, is complex, nuanced, and nonlinear”.

4. Research Methodology

This section provides the rationale for the research methodology that was chosen for this research. The study used a mixed method, multiple-case study design. The section is divided into three main parts. The first section provides an overview of the research design, followed by a description of the population and sampling of the study participants. The third part presents a summary of the research instruments, and how their reliability and validity were established.

Research Design

A mixed method research design and a multiple-case study approach were used in this study. The study sought to comprehend “an experience from the respondents’ point of view”, the Geography teachers, who teach GIS [52]. According to Yin [53], a case study is an investigation that investigates a contemporary phenomenon in its real-life context. The study used a multiple-case study (10 high schools in the Frances Baard District of the Northern Cape Province) to investigate Geography teachers' teaching methods when teaching GIS topics.

An explanatory sequential research design was used in the study. First, quantitative data was gathered and later, qualitative data was collected, in order to explain the quantitative results [54]. Quantitative data was collected through Likert-type questionnaires, while qualitative data was collected by observing the teachers in the classrooms, and by pre- and post-classroom observation interviews. Thus, the study investigated the teachers’ teaching of GIS technology (phenomenon of interest), in a real-world situation (teaching and learning), with real people (Geography teachers), in a real-world setting (high schools) [55].

Population Sample

During the first phase, quantitative data was collected through questionnaires distributed to 70 teachers in the Frances Baard District. The researcher distributed questionnaires to all the Geography teachers in the district. Frances Baard District was chosen out of the five districts in the province, because the district has a variety of schools which include public and private (independent) schools. Some of these schools are found in urban areas and others in rural areas. The district was also chosen because it has some former model C schools and township schools, which gave the researchers a wider cross-section of schools in which to carry out this research. Teachers were given some of the questionnaires while attending a workshop on matric results analysis at the Elizabeth Conradie High School in Kimberley on 26 February 2016, while some questionnaires were sent to teachers who did not attend this workshop. After distributing the questionnaires to the 70 teachers, the researcher eventually managed to get 50 responses which gave a response rate of 71.4%.

In order to gain a better understanding of the phenomenon under investigation, ten teachers from ten different schools in the district were conveniently chosen for lesson observation and interviews. Five teachers were drawn from township schools, 3 from rural schools and 2 from former Model C schools. The lesson observations were done to capture the variation of pedagogical approaches used by different teachers and grades while teaching different GIS topics. As noted by Mack *et al.* [56], purposive sampling compels a study to categorize subjects according to an identified criterion centred on the research's problem. This convenience sampling was done to obtain as much information as possible from participants who are likely going to provide meaningful information [57] about GIS teaching.

Research Instruments

In order to obtain quantitative data from the teachers, the researcher administered a questionnaire that comprised closed-ended Likert-type questions. Most of the question items had been adapted from previous related studies on the TAM model [58]. Question items in this study used Likert Scale ranging from 1 as "Strongly disagree" to 5 as "Strongly agree".

The questions for the interviews were generated from the findings of the questionnaire, to further probe the understanding of the issues which were being researched. A semi-structured interview guide was used for this purpose. This had set questions that allowed flexibility in the interview process. The interview guide included questions on the content of the GIS taught, pedagogical approaches used, reasons for the choice of the pedagogical approaches, knowledge about GIS, training of GIS, and experiences with GIS teaching. The data was collected over a period of three years, that is, from 2016 to 2018.

The lesson observation was employed in this research in order to establish the pedagogical approaches put into practice by the teachers. Each teacher was observed once due to time constraints, logistical problems, and arrangements with the schools and the teachers. The lesson observations were done during the first and second terms of 2016 and 2017. The lesson observations were done during these terms because this is when GIS topics were taught, and the teachers were willing to be observed. Initially, we had planned to observe at least two lessons per teacher. However, we abandoned this intention due to time constraints.

Instrument Reliability Tests

The reliability of the final instrument was ensured by using the internal consistency and average inter-item correlation reliability method in order to test and retest the reliability of the questionnaire. The researchers applied the Cronbach's alpha (α) to check for internal consistency reliability [59] of all the questions with four or more question items, and an average inter-item correlation reliability for the cases where items were less than four items. The dependability of the questionnaire was determined by correlating the findings with the literature review.

The demographic results included information gathered through interviews and questionnaires. Participants were asked about their gender, age, highest educational qualification, area of specialization, type of school they taught in, and teaching experiences. The results of sixty (60) respondents are discussed in the following sections. There were 40 males and 20 females who participated in this research. The age distribution of the participants is reflected in Figure 1.

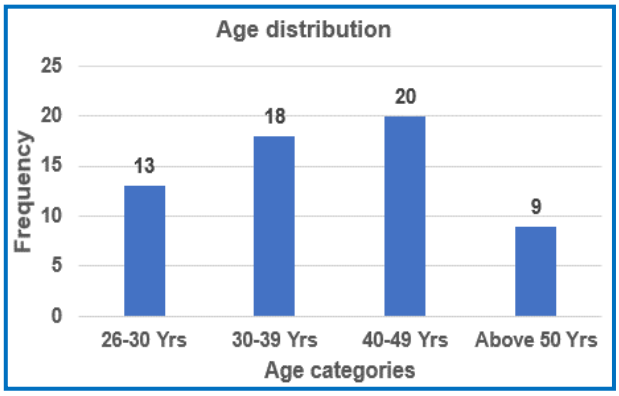

Figure 1. Age distribution

As shown in Figure 1, the majority (n=20) of the Geography teachers who participated were between the ages of 40 and 49. They made up 33.3 percent of the participants, while the 30-39 age group made up 30%. Age group 26-30 and above 50 had the least percentage 21.7% and 15% respectively. This represents a good age range for the study.

The race representation of participants is shown in Figure 2. According to the empirical findings, Black African Geography teachers dominated the survey. The results show that 33 of the teachers were Black Africans, accounting for 55 percent (n=33). Coloreds had the second highest number of respondents (n=16), accounting for 26.7 percent of all participants. The White ethnic group was the smallest. It had 18.3 percent (n=11).

The results show a fairly accurate demographic representation of the Northern Cape Province's population. Figure 3 depicts the results for the participants with the highest educational levels. The results in Figure 3 show that 48.3% (n=29) of the Geography teachers had B.Ed. degree, 23.3% (n=14) had BSc degree, 11.7% (n=7) had BA degree, 13.3% (n=8) had PGCE, and 3.3% (n=2) had Masters' degree.

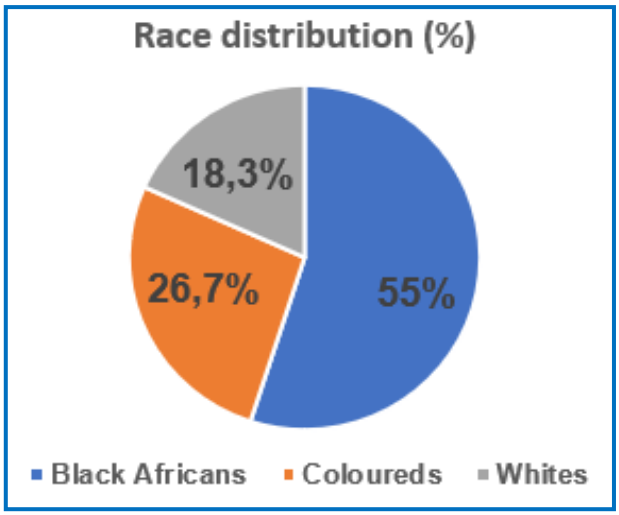

Figure 2. Race distribution

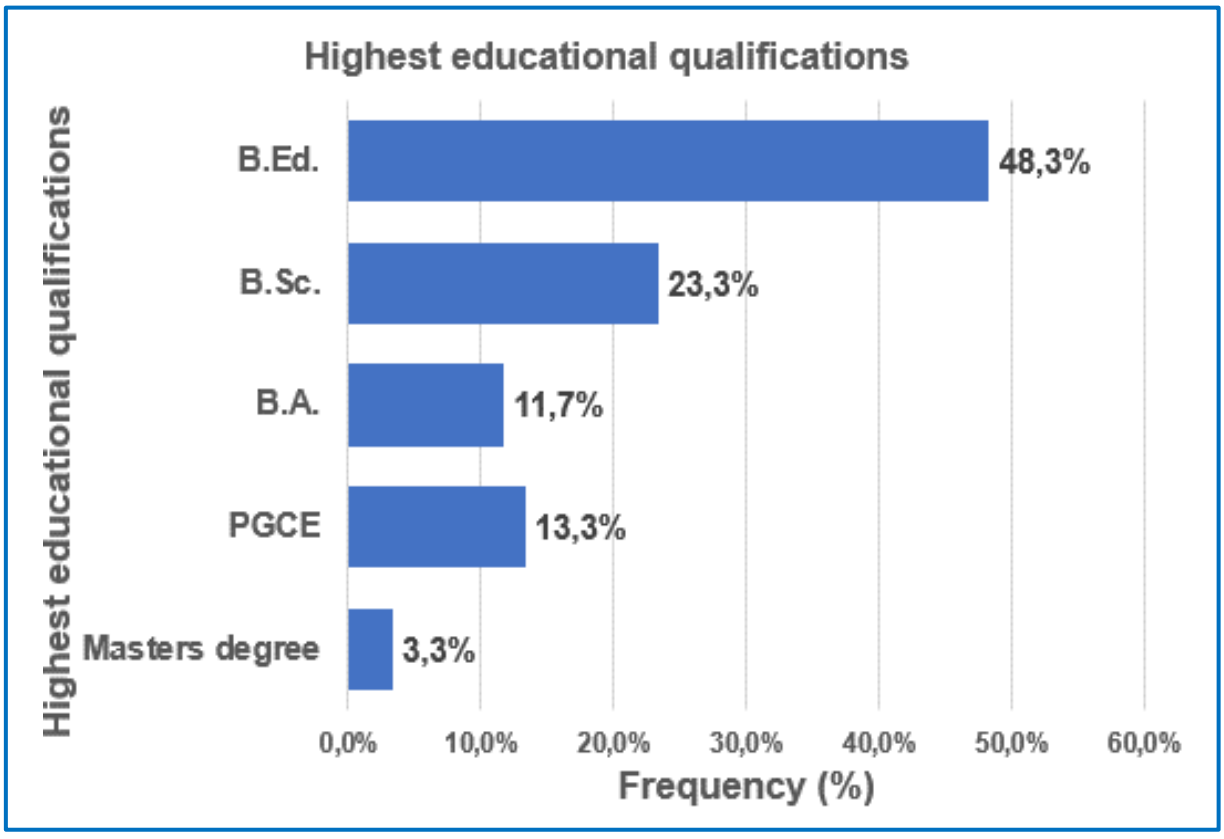

Figure 3. Highest educational levels of Geography teachers

Figure 4 shows the number of years teachers had been teaching. The majority (n=24) of responses had teaching experience ranging 10-14 years. Fourteen (n=14) had teaching experience of 0-4 years. The results on the distribution of teaching experience depicted a normal graph.

The teachers who participated in this research were made up of teachers who had vast teaching experience in the profession and those who had just joined the profession of teaching.

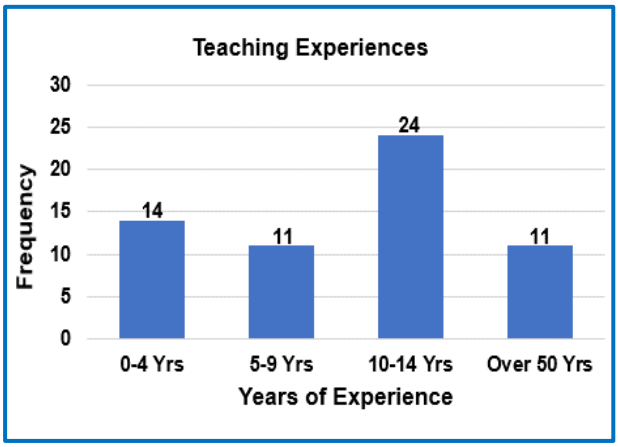

Figure 4. Teaching Experiences

As illustrated in Figure 5, the majority (48.3%; n=29) of the participants in this research stated that they specialized in Geography subject teaching, and 40% (n=24) specialized in other subjects other than Geography.

About 11.7% majored in other subjects such as History, English and Life Sciences when they were doing their training at Universities and Colleges.

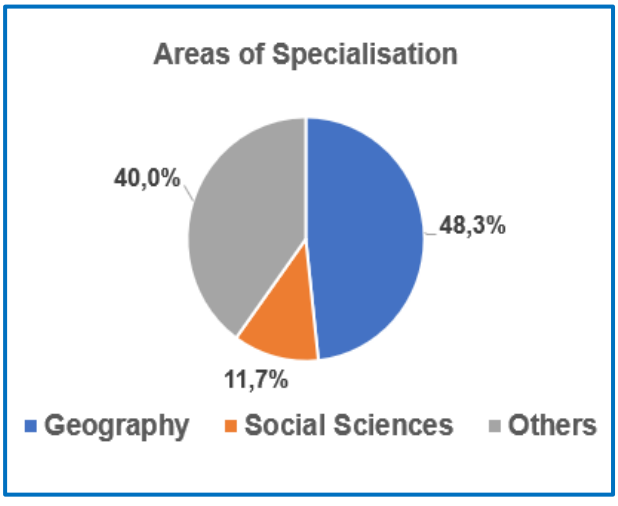

Figure 5. Areas of specialization

The majority (51.6% n=31) of the teachers stated that they taught more than 40 students in class. 31.7% (n=19) of the teachers taught classes with students ranging 30-39 students. Ten (n=10) responded that they taught students ranging 16-29 (see Figure 6).

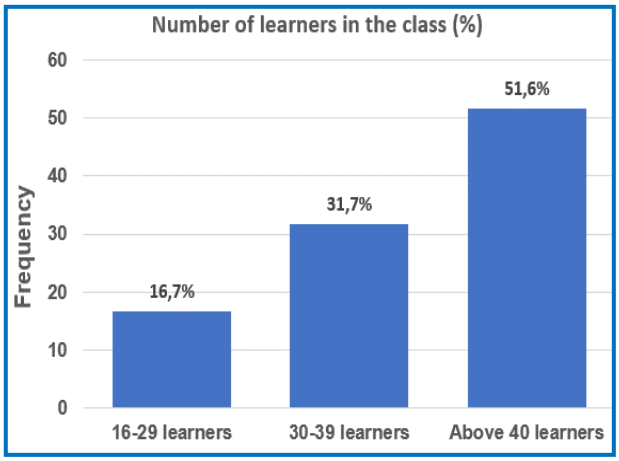

Figure 6. Number of students in the Geography class

Of the 60 teachers, 55 (92%) came from public schools and only 5 (8%) came from private schools as shown in Figure 7.

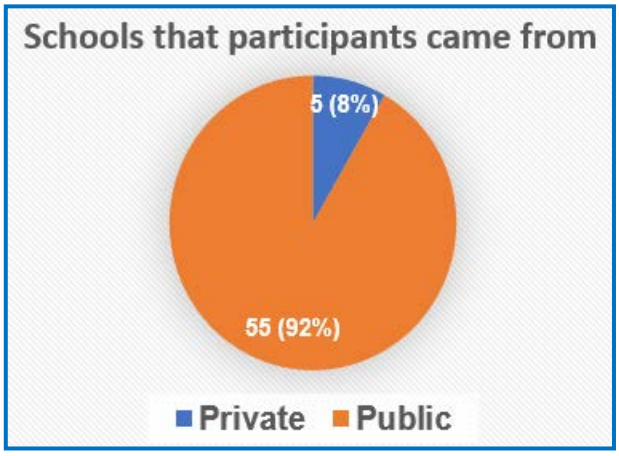

Figure 7. Types of schools

Pedagogical Approaches Used by the Teachers

The findings on pedagogical approaches from the 50 participants who completed the questionnaires are summarized in Figure 8.

The majority (36% n=16) of the teachers used explanation teaching method, 32% (n=12) stated that they used questioning method, 20% (n=10) used lecturing teaching method, 5% used class discussions and groupwork. Overall, the dominating pedagogical approaches used by the teachers were teacher-centred (see Figure 8).

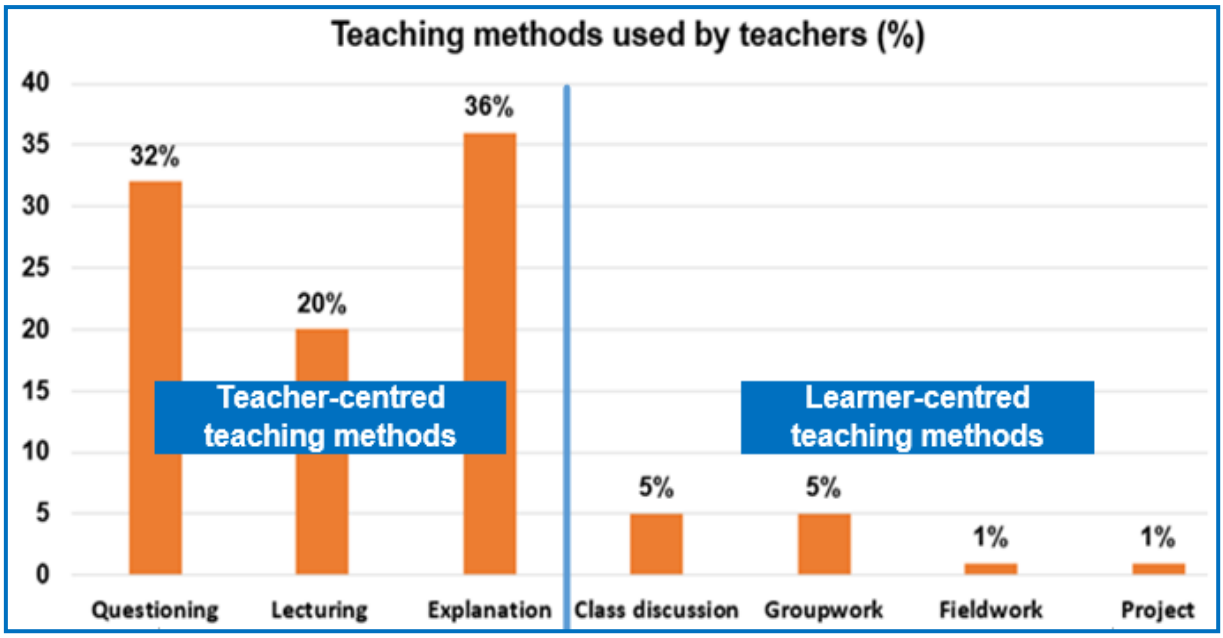

Figure 8. Teaching methods used by participants to teach GIS (data from the questionnaire (n=50)

Table 1. A summary of teaching methods used by the 10 teachers

Teacher	Summary of the teaching methods
Teacher van Wyk in school 1	Explaining, questioning, Group work, class discussion, demonstration and modeling
Teacher Tau in school 2	Explanation, questioning and lecturing, practical (multiple)
Teacher Fatima in school 3	Class participation, practical demonstration, group work (Multiple)
Teacher Mable in school 4	Explaining, questioning and lecturing
Teacher Robson in school 5	Visualisation, peer instruction, collaborative problem solving
Teachers Douglass in school 6	Hands on approach, experimentation, lecture method, visualization, peer instruction, group work, collaborative problem solving
Teacher Letimia in school 7	Explaining, Questioning
Teacher Rua in school 8	Explaining, Lecturing, questioning method
Teacher Ngubane in school 9	Explaining, Lecturing method
Teacher Abigail in school 10	Lecturing and explaining

From the 10 teachers who were interviewed, 8 of them (80%) stated that they used Explaining, Questioning and Lecturing teaching methods. The majority of the teachers who participated in this research broadly used teacher-centred pedagogical approaches to teach GIS. The teaching methods commonly used by the 10 teachers are summarized in Table 1. Data collected from both interviews and lesson observations showed that the majority (n=8) (Table 1) used an explanation pedagogical approach. Below are some of the extracts from the interviews and the results from the lesson observations.

Teacher Tau in school 2 (LO2) who was observed teaching the topic: Components of GIS in Grade 10 used explanation and questioning pedagogy. Teacher Tau's class had 59 learners. On the day of the lesson observation, 7 learners were absent. Teacher Tau started off his lesson by recapping the previous lesson's key points on the meaning of GIS, its history and functions, and why it is important.

Teacher Tau asked the question: "*What is GIS"?* The learners put up their hands and Teacher Tau picked one learner at the back of the class who gave the answer that GIS was Geographic Information Systems. Teacher Tau further probed the class by asking "what does GIS do"? No learner was able to respond to the question. Teacher Tau then responded by giving an explanation of what GIS is.

"Yes, GIS is an acronym which stands for Geographic Information Systems". "*It is a computer system that is designed to capture, store, manipulate, analyze, manage, and display various types of spatial or geographical data*".

After recapping the previous lesson's key concepts, Teacher Tau introduced the new topic on the components

of GIS by putting some pictures of GIS components on the chalkboard, and instructed the students to give the names (Figure 9).

Figure 9. The components of GIS

The following extracts are the explanations of the functions of the GIS components which were given by Teacher Tau in his class.

Hardware (Computers)

A computer on which GIS runs is referred to as hardware. GIS software is executed on a computer's hardware. A smart phone can also be used as a piece of hardware in this case. For example, we can take a picture using the cell phone and download it on the computer. *"This is simple, isn't it? Also, we can use a GPS instrument"*. The teacher showed a GPS instrument and a laptop he had brought to the class as examples of hardware used in GIS.

Software

"GIS software includes capabilities and tools for storing, analyzing, and displaying geographic data. Tools for entering and manipulating geographic data are important software components. A database management system (DBMS) includes tools for spatial querying, analysis, and visualization"

Data

"Information that can be collected and saved in GIS software is referred to as data. A GIS can combine spatial data with other data sources and even employ a database management system to edit data and generate maps, graphs, and charts."

People

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

The other teacher who used explanation and questioning pedagogy was Teacher Mable in school 4 (LO4). Teacher Mable was observed teaching the topic: Querying and Statistics analysis in Grade 12. Teacher Mable's class had 55 learners. On the day of the lesson observation, 5 learners were absent. Teacher Mable commenced the lesson by checking the learners' homework and giving feedback to the learners. During the homework feedback, the teacher involved the learners by asking them to give the answers to the homework questions. The following quotations are some of the questions and responses given by teacher Mable.

"What is buffering?" Few learners put up their hands. Before teacher Mable could pick up the learners for responses. She asked the class, *"Why are you not putting up your hand? Didn't you do the homework"?*

Afterwards, the teacher picked one learner to give the answer. The teacher further gave a full answer by saying *"A buffer is a distance-based categorization. It entails calculating distances in all directions from an object. All three types of vector data can be buffered: point, line, and area. A polygon file is created as a result of the buffer."*

The teacher asked the second question: "What is data integration?" Again, few learners put up their hands. The teacher picked up one learner who answered the question wrongly.

The teacher said, *"Thank you for trying"* and went on to give a full explanation of what data integration is. "Data integration" refers to the process of merging data from several sources and presenting it to users in a cohesive manner. *It is like combining cows, donkeys and goats in one kraal. For example, we can combine population data and area data to calculate population density"*

After that, the teacher introduced the new topic of the lesson. She wrote the topic on the chalkboard and asked one of the learners to read from the textbook. The teacher then moved around the classroom showing the learners the statistical table in the textbook. The teacher asked the class *"What is querying?* No one answered the question. The teacher then wrote the definition of querying on the chalkboard without explaining the meaning of the concept. She just read aloud what she had written on the chalkboard. *"A query layer is defined by a SQL query. Query layers in ArcMap allow both geographical and non-spatial data from a database to be easily linked into GIS projects."*

Both teachers used explanation and questioning methods differently. Teacher Tau (LO1) involved many learners in his explanation as he was teaching the lesson. Learners were involved in the lesson when they were asked to name the GIS components. Teacher Tau's explanation was structured and ordered very well, as he explained components of GIS one after the other, in a logical order, starting with hardware followed by the software, and then data. The explanation he gave in the lesson gave ideas of what the components of GIS do. The teacher used an interpretive explanation. It was aimed at clarifying concepts. The teacher also mixed explanation pedagogy with other appropriate techniques. He accompanied

explanations with questions, demonstrations and illustrations. He supported verbal explanations with visual support when he used the charts with some pictures of GIS components he was discussing in this lesson. Instead of using one sense, sense of hearing when the teacher was explaining the functions of the components, the learners could also use the sense of sight for seeing the pictures of the GIS components on the white board. He further strengthens the sense of sight and hearing by making the learners touch and feel the GPS instrument he brought to the lesson.

In teacher Mable's class (LO4), the learners were partially involved in the construction of knowledge. The explanation of the concepts was not logical and well structured. For instance, the acronym SQL when the teacher was giving the definition of querying data was not explained. Teacher Mable's explanation techniques failed to make the learners understand the concepts learnt in this class. The explanations given were not repeated in different ways to ensure that learners understand the concepts. The learners were not fully engaged in the lesson. The closest time when she was trying to engage the other senses of the learners beside the sense of hearing was when she walked around the class showing the table of statistics in the textbook.

The learners who tried to ask some questions during teacher Mable's lesson were not accommodated. The teacher could not give satisfying responses to the questions asked by the learners. Seemingly, teacher Mable's knowledge of the concepts was very shallow. The learning environment in teacher Mable's class was fairly good. Desks and chairs were neatly arranged, giving room for the teacher to walk around monitoring learners' progress. However, the teacher did not utilize all the advantages the classroom environment had to better her pedagogical approaches.

Questioning pedagogical approach was second most widely used in this research. The data from the interviews and lesson observations showed that the majority (n=7) used questioning method. Data from the questionnaire survey also showed that the majority (22%) of the teachers used questioning method. For example, teacher Mable (LO4) used it largely to manage her classroom. During the lesson she asked the learners:

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

This is an example of classroom management type of questioning, which does not check understanding of the learners or motivation of the learners. Teacher Mable (LO4) seldom used questioning approach to foster learning and understanding. For the questioning technique to be effective, it should be used at the correct time. The teacher should make a decision when to use questions.

Teacher van Wyk in school 1(LO1) was observed teaching the topic: Remote sensing and resolution in Grade 12. He used questioning, explanation and modelling pedagogical approaches. Teacher van Wyk's class had 36 learners. On the day of the lesson observation, 1 learner was absent.

The teacher commenced the lesson by checking the homework. Teacher van Wyk used questioning pedagogy to check understanding of the previous concepts taught. The following are the extracts of the questions asked during the lesson.

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

After asking each question, the teacher paused and repeated the question, giving the learners time to respond to his question. The sequencing of the question helped to probe the understanding of the learners. After the learner had given the answer, the teacher probed further to check whether the learner was sure of the answer he/she was giving. For instance, one learner said that one-way remote sensing took place was passive sensing. Teacher van Wyk probed further by asking the learner, *"can you explain what passive sensing is and what the different between passive sensing and active sensing is?"*

After giving feedback on the homework, teacher van Wyk introduced the new topic by asking questions that connected the previous section with the current topic. He explained that remote sensing was information we get from space, the air, and ships (satellites).

After explaining the concept of remote sensing, the teacher introduced the concept of resolution to the class. He asked the learners to take out their cell phones and asked them to take a picture and demonstrate what resolution is by zooming in and out. He then asked the students in pairs to describe what happened to the picture. From the beginning of the lesson up to the end of the lesson, teacher van Wyk used the learner-centred pedagogical approach in his teaching. He involved the students in the construction of knowledge by using questioning, explanation and modelling pedagogical approaches. The teacher was innovative in his approach. The teacher exhibited a deep understanding of the content matter he was teaching.

The majority of the teachers cited several reasons why they used the approaches they used. Some of the reasons are given in Table 2.

Table 2. Reasons for using particular pedagogical approaches and teaching methods (data from the lesson observation)

Pedagogical approaches and Methods	Reasons for using the approach
Explaining (TC)	Lack of knowledge Easy to use Familiar
Questioning (TC)	Familiar Less preparation
Lecture method (TC)	Lack of resources It gives the teacher autonomy over the class Easy to control and manage the learners Helps to cover a lot of content Less time-consuming Large classes
Class discussion (TC and LC)	Learners learn from each other, share ideas Learner-centred
Demonstration (TC)	I use this method to show the learners how GIS works So that learners can understand the concept much better
Practical activity (LC)	GIS needs hands-on experience; I give them some practical activities so that they can see that GIS can solve real life problems
Project assignment (LC)	Learners can learn more when they share ideas It promotes teamwork and corporation

Key:
TC- teacher centred
LC-learner centred

In her interview after the lesson observation, teacher Letimia in school 7 (I,7b) spoke about not having access to enough resources in her school, which is a quintile one school in the township. Therefore, they depended on government funding, which was not always enough.

The next narrative is of Teacher Abigail in school 10 (I, 10b). Teacher Abigail also taught at a poor school in the rural area, with no access to computers. Teacher Abigail herself had never done computers. She had a cell phone. She only used the cell phone for answering calls and texting people. She knew her learners in class had cell phones and she never thought of using cell phones for GIS lessons. She also preferred to teach using the textbook. She started the lesson by asking the learners questions whether they knew what buffering was and went on to introduce the lesson of the day.

Clearly from teacher Abigail post interviews, shortage of physical resources continued to determine the choice of teaching methods teachers choose when teaching GIS. Teacher Abigail (10, 10b) also said:

I used the lecture method because it helps me to cover more content work than using group work and makes the learners listen and less disruptive in the lesson.

Large Classes

The majority (80%) of the teachers interviewed stated that they used explanation, questioning and lecturing teaching methods to deliver their lessons because of large classes. Teacher Ngubane in school 9 (I9,9b) said that:

If I use group work, it will be very difficult to control the class because I teach a lot of learners (60) in one class. Putting the learners into groups will take a lot of time and the class is difficult to manage.

Teacher Ngubane (I9, 9b) is more worried about the autonomy of the class than the concept he was teaching. The size of the class and lack of resources coupled with his incompetence to use computers tend to detect the methodology employed by teacher Ngubane. We also observed that most of the teachers who taught large classes used Lecture, Explanation and Questioning methods. They said they could not use other methods such as group work and class discussion because they were time-consuming and made learners noisy and uncontrollable. Learning in such classes was more teacher-centred than learner-centred.

It was also observed that teachers who taught small classes had a variety of pedagogical approaches to their disposal. The teachers in schools such as former model C schools, are comfortable to employ a variety of teaching approaches in each lesson. The teachers could use a brief lecture (exposition) method at the beginning of the lesson as the teacher introduced the concepts to the learners. The exposition could be in the form of a PowerPoint presentation and put the learners into groups to discuss the concepts and ask the learners to give feedback. Each group would be given five minutes to give feedback to the class. We found that there is more learning and grasping of concepts in small classes than in a large class. Most of the lessons in these schools were learner-centred. Learners could collaborate with each other and share some ideas.

Lack of Knowledge in GIS

The majority of teachers (84 percent) stated that they had a basic understanding of GIS. Twelve percent (12%) (n=6) stated they had a good knowledge of GIS and 4% indicated that they had weak knowledge of GIS. The crosstab in Table 3 revealed that lack of solid GIS knowledge cuts across all the age groups surveyed.

Table 3. Age * Knowledge about GIS

Crosstab: Age*Knowledge about GIS					
Age	**Count**	**Weak**	**Fair**	**Good**	**Total**
26-29 Years	Count	0	10	2	12
	% of Total	0,0%	20,0%	4,0%	24,0%
30-39 Years	Count	1	14	1	16
	% of Total	2,0%	28,0%	2,0%	32,0%
40-49 Years	Count	1	14	2	17
	% of Total	2,0%	28,0%	4,0%	34,0%
≥50Years	Count	0	4	1	5
	% of Total	0,0%	8,0%	2,0%	10,0%
Total Count		2	42	6	50
% of Total		4,0%	84%	12%	100,0%

The majority of teachers, as shown in Table 4 (98%), stated that they lacked proper training in GIS and therefore, needed training in order for them to be able to teach the GIS effectively. This view was also shared by the teachers we interviewed. They stated that they did not have enough training in GIS. Ninety-eight percent (98%) stated that they needed training and only 2% disagreed.

Table 4. Gender *Teachers need GIS training Crosstab

Crosstab: Gender*Teachers' need GIS training					
Gender	**Count**	**Disagree**	**Agree**	**Strongly Agree**	**Total**
Female	Count	0	3	13	16
	% of Total	0,0%	6,0%	26,0%	32,0%
Male	Count	1	9	24	34
	% of Total	2,0%	18,0%	48,0%	68,0%
Total Count		1	12	37	50
% of Total		2,0%	24,0%	74,0%	100,0%

5. Discussion

The study revealed that the majority of teachers employed the Explaining, Questioning and Lecturing teaching methods. Some of the reasons given by the teachers for using these teaching methods were that, at times, they lacked GIS knowledge, the methods were easy to use, and the methods would make it easy to control and manage the learners. This finding seemed to agree with studies that showed that teachers used questioning method for managing the class rather than making the learners understand the concepts [29].

The finding that some of the teachers had never had an opportunity to use the computers for GIS was very interesting. This forced teachers to teach GIS in their classes using the chalk board. They wrote the notes and then questioning the learners on the notes they had written. What was apparent from the teachers where there were no resources at the school, they had no option but to use a textbook they had access to, and the learners had access to and to use a chalk board which is a resource which is available in his class to teach GIS theoretical [3, 60, 61, 62]. This finding confirms that resources were one of the barriers to technology integration [15]. Therefore, shortage of physical resources seems to be one of the major factors in determining the choice of teaching method teachers choose to use when teaching GIS. Teachers concentrated on using the little material available and neglect the use of media and technology [63].

According to reference [63], teachers stick to textbooks and are too busy to get more relevant information from a variety of instructional materials. When teaching, they frequently concentrate on a single source of information, the textbook. This was common in most of the teachers observed in this research. The majority of the teachers used the textbook as the only source of information. In some schools, especially in rural schools, textbooks were not enough for all the learners in the class. As a result of lack of resources and lack of innovation, the majority of teachers do not appear to use a diversity of instructional strategies. Even if the teacher discovered that the students do not understand or grasp the idea being taught, he or she was not required to attempt another method.

There was a big gap between township and rural schools and former model C schools in terms of physical resources availabilities. Most of the high schools in rural and township schools lacked physical resources such as computer labs, data projectors, internet connections and smart boards etc. Contrary, the former model C schools can afford most of all these equipments. The polarization of schools, which dates back to the years of apartheid, continues to affect the implementation and teaching of GIS in high schools [4, 60, 64].

The observation that teachers who teach small classes have a variety of pedagogical approaches to their disposal, agrees with assertions made by [47] and [48]. They claimed that small classes provided for higher-quality learning opportunities, the development of teacher-learner relationships, more individualized and learner-centric training, increased teacher morale, and fewer student misbehaviors.

6. Conclusion and Recommendations

The findings of this study revealed that teachers who teach GIS in Geography in high schools in South Africa's Northern Cape Province primarily employ a teacher-centered pedagogical approach. The commonly used pedagogical approaches were Questioning, Explaining and Lecturing. The major reasons they cited on why they used these pedagogical approaches were lack of physical resources, large classes, lack of training and lack of discipline in the schools they teach. Based on the lesson observation, the study discovered that the majority of teachers lacked technological pedagogical content knowledge (TPCK). Most the teachers were also struggling with the content knowledge in GIS, and as a result, their pedagogical approaches were not firmly connected to the content. With today's modern methods of teaching Geography, and particularly GIS, both the teacher and the students should be able to acquire knowledge on their own. Learners should be exposed to the skills which allow them to acquire knowledge and skills in life. Therefore, such pedagogical approaches used to teach GIS should be more practical, hands-on experience. For learners to have the knowledge and working skills required in today's labor market demands that the learning process should model critical aspects of critical thinking, reasoning, observations, and research. GIS should be taught in a practical way. Geography teachers should embrace the use of problem-based learning (PBL), which the researchers regard as a more practical approach to learning GIS. This is one technique to realize the emphasis on pedagogical transition in Geography from a behaviorist to a more constructivist approach to learning.

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