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Assessment in the Social Sciences: GIS Training and Assessment for Pre-service Geography Teachers in a Rural University

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ABSTRACT Geographical information system/s (GIS) is a relatively new inclusion in the school curriculum in South Africa. The training and assessment of pre-service teachers is crucial for the successful implementation of GIS in schools. This article explores the impact of GIS software in the training and assessment of student teachers in Geography Education at the University of Limpopo. The students are exposed to mainly rural schools where the use of technology in teaching is rare. Therefore this article examines the exposure of student teachers from rural backgrounds to GIS software and assesses their mastery of the software. The research reports on the process involved in training the students to use GIS software; assessment of students' competency in drawing specific maps; and students' self-assessment in the form of reflections. Data were gathered using questionnaires and from a practical assessment using GIS software. The data were quantitatively analysed to determine problems faced by individual students in execution of the assessment task. The findings indicate that students grasped the basic skills required to utilise GIS software, but need more training in complex exercises. Findings from the questionnaires indicated that students benefitted from the training and assessment tasks. Once the technological skills were mastered, students could attempt the assessment task with greater ease. It is recommended that Geography Education students should complete GIS as a module that is fully assessed. In this way assessment tasks can become more complex, and the skills gained can be meaningfully utilised by teachers.

INTRODUCTION

A geographical information system (GIS) is a computer-based information system that enables the capture, modelling, manipulation, retrieval, analysis and presentation of geographically referenced data (Reinecke 2005). Since society is becoming more spatially enabled, geography and GIS are becoming embedded in mainstream decision-making and enterprise systems (Schmitz 2009).

GIS has been successfully implemented throughout South Africa in various organisations in the national, provincial and local government spheres (eGovernment 2005). The South African Government sees the value of using GIS in other spheres, such as disaster management and provision of utility services like water billing. Successful use of GIS has been recorded in crime management (Eloff and Prinsloo 2008, 2009), health care (Tsoka and Le Sueur 2004; Cronje and Barker 2006; Busgeeth and Siegfried 2008; Moodley 2009), and at municipal level for urban spaces (Spocter 2006), for housing (Furter 2005; Breytenbach 2010) and in local government (Nel 2008).

GIS software is widely used in the private sector for a variety of applications, such as global positioning satellite (GPS) technology (Wilhelm 2009). Furthermore, GIS technology is widely used for various environmental projects involving animal movement (Fabricius and Coetze 1992), marine ecosystems (Scott 2006), monitoring of soil erosion (Le Roux et al. 2007) and water-related studies (Vorster et al. 1995; Mtetwa et al. 2003; Van der Post 2004; Getz and Ryan 2005; Mhangara 2008; Mulder and Grab 2009; Hoffmann and Winde 2010).

Therefore, it makes sense that it would also be included in the curriculum that is taught in schools. In many countries across the world, such as the United States (USA), United Kingdom (UK), France, Finland, Germany and Turkey, GIS is taught as part of the curriculum, and practical application using technology forms a crucial part of this teaching. In the South African school curriculum, GIS was included as a section in the Revised National Curriculum Statement (RNCS) in Geography. It also appears in the new Curriculum and Policy Assessment Statement (CAPS) (Department of Education 2010). The curriculum contains the basic theory of GIS. There is no provision for training in the practical application of GIS using computers. Since GIS applications work using technology, the implication is that if learners are to gain practical experience in this section, they would need access to computers and the necessary software. A small percentage of schools in the public schooling system do have computers for learner use, and a yet smaller percentage has access to funds to purchase the necessary software to effectively teach GIS (Singh 2004). Rural schools are the victims of poor infrastructure, few resources and facilities (Singh 2004), and their basic resources do not include technology for learner use.

At higher education institutions (HEIs) in South Africa the divide between historically black universities (HBUs) and advantaged institutions still exists. Many of the HBUs are situated in rural areas. It is within such a context that this study examines the training and assessment of pre-service Geography teachers in the use of GIS software. Many of these pre-service teachers come from the rural provinces of Limpopo and Mpumalanga, and they are likely to be employed in these provinces. Their first exposure to computers is at university during their first year of study.

As the school curriculum evolved to include GIS as a section, the training of these Geography teachers had to accommodate inclusion of this section in the course outline of the content modules for Geography Education. It also became necessary to purchase the necessary software and train and assess these pre-service teachers in using the software. The most effective way of establishing their mastery of this skill was to assess their ability to use the software for different tasks given to them. This article reports on this training and the assessment process.

The next section gives an overview of GIS in basic education and higher education both locally and internationally. The purpose is to locate GIS within the education sector in order to develop a background against which the research in pre-service training and assessment of teachers was carried out.

Overview of GIS in Education

In the arena of basic education, the teaching of GIS in schools in different countries is well documented. One commonality in most countries is the problems associated with implementation of GIS in the curriculum. Green's (2001) GIS sourcebook for schools gives a detailed account of the implementation of GIS in schools across different countries. Although GIS was introduced in schools in the USA in the early 1990s, problems with its implementation are found across many states. However, in comparison with their European counterparts, more strides have been made in the USA than in European countries. Taking into consideration the complexities that developed countries have experienced with GIS in the school curriculum, it is expected that developing countries would fare worse. However, one common problem with the roll-out of GIS across countries is lack of funding. In developing nations the lack of funding and institutional commitment has prompted Reinecke (2005: 40) to argue that "Decision makers in developing countries must be educated about the strategic value of GIS so that they build institutional capacity into their organisations and allocate on-going funding to GIS".

In introduction of GIS in schools in the USA progress was seen as more successful, in part as a result of the general GIS and educational activities of the National Center for Geographical Information Analysis, which initiated a school-orientated GIS programme (Green 2001). The impact of such initiatives may be found in Wanner and Kerski's (1999) research into the impact of inquiry-based lesson modules that use GIS technology in teaching. However, the concern is whether GIS, like other applications of technology that have been implemented to enhance instruction, will have a lasting impact or is just a passing fad (Coulter 2003). Coulter (2003) proposes that in order for GIS to become a meaningful learning tool, larger issues of curriculum, assessment and teaching need to be attended to.

In schools in England, despite the presence of computers and the software, "only a handful of schools are using GIS" (iGuess Project 2009). An advance in English schools is a GIS teaching resource in the form of a new textbook which has exercises and software designed to help teachers of Geography at A-level (when students are 16-18 years old). Of concern is the lack of strategy or consistent attempts to train and assess teachers in GIS. The current ad hoc training and assessment is of little relevance and lacks inspiration (iGuess Project 2009). The iGuess project also reports that there is a gap in research in this area of education, and in relation to teacher training concludes (2009:32) that “GIS is now in the English curriculum with little guidance, few resources and no research on what teachers actually need”. The iGuess Project also reports on the status of GIS implementation in other European Union (EU) countries like Austria, Belgium, Bulgaria, Finland, France, Greece and Hungary.

In the Finnish context, implementation of GIS in schools is sporadic. This is linked to a curriculum that offers GIS as an elective. A shift to the constructivist approach in learning focuses more on problem-based learning and inquiry-based learning methods. This means that learners become active members of their own learning and process geographical information on real-world issues, collectively building up knowledge through inquiry and reflection (Johansson 2003). The iGuess Project (2009) reports that computers and GIS software are available in schools together with GIS workbooks in Finnish, although GIS is not widely taught in Finnish schools. It is mainly taught by teachers who received GIS training during their university education. It was suggested that teachers in Finland need in-service training, better access to databases and good, ready-to-use pedagogical examples of how to use GIS in schools.

Turkey is perhaps a good example where an effort is being made to make GIS more teacher-friendly. Although GIS has been incorporated into the Turkish secondary school Geography curriculum since 2005, Turkey has been struggling to make GIS a widely used tool in Geography lessons (Demirci and Karaburun 2009). In a quest to assist teachers, a GIS book was launched in 2008. By combining theory and practice, the book and software package provides teachers with data, GIS software, GIS-based exercises, methodology, and other necessary guidance for using GIS in their lessons (Demirci and Karaburun 2009).

The Environmental Systems Research Institute (ESRI) has been very active in promoting the use of GIS in schools and universities across the world. With branches established in most countries, this organisation is popularly known for its ArcView software that is used in many schools. It also actively campaigns for GIS use in schools by providing free software. The software used by pre-service teachers in this research was also purchased from ESRI. In Canada, TYDAC SPANS provides GIS software for schools. Besides both ESRI and TYDAC’s involvement in providing GIS software, the IDRISI software package in the USA has also proved very successful as a GIS toolbox in schools (Green 2001).

Although GIS has recently (2006) been introduced into the school curriculum in South African schools, it has been in use in industry and the corporate world for a number of years. The challenge has been to develop a national skills strategy which will holistically address GIS issues across all sectors of the country, including higher education. To this end, workshops on GIS skills development were held in four centres across South Africa in 2006. Some of the recommendations included the need for a skills profile audit of GIS needs, establishment of GIS learnerships (sponsorship between a learning institution and industry where the institution provides a combination of theoretical and practical training at a particular workplace), professional registration of GIS-trained people, curricula standardisation (at tertiary institutional level to bring all GIS graduates to the same academic level), training of teachers in GIS and the new curriculum, creation of an educational model for GIS in terms of content and skills requirements, and a national identity for GIS (National Department of Rural Development and Land Reform, Directorate: National Spatial Information Framework (NSIF) 2006). There are, however, other issues that would have to be factored into a national strategy for GIS in South Africa.

Singh (2004) has identified politics as one of the biggest stumbling blocks in the growth of GIS. Singh (2004) also argues that poverty and literacy are major problems in developing countries. Poverty impacts on the speed at which GIS expands, since the cost of technology is balanced against other priorities such as health care and food security. In a country such as South Africa, which has 11 official languages, providing GIS software in local African languages is also a challenge.

The new CAPS for Geography for Grades 10 - 12 gives a clear outline of the skills and techniques that need to be taught for GIS. This is illustrated in Table 1.

Pre-service teachers are expected to be competent in all of these sections. This means that their training must include assessment that ensures competency in all areas of GIS. Due to the instruction time of 14 hours over a 3-year peri-

Table 1: GIS skills and techniques (Department of Education 2010: 20)

Grade 10	*Grade 11*	*Grade 12*
• Reasons for development of GIS • How remote sensing works • GIS concepts: spatial objects, lines, points, nodes and scales	• 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	• 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

od, the Geography teacher does not have the space or time to introduce the practical component of GIS that uses technology. In addition, the only mention of a GIS-related assessment is that learners should demonstrate competence in "working with concepts, data, procedures related to GIS" (Department of Education 2010: 67). It is against such a background of new curriculum reform related to GIS that pre-service Geography educators need to be trained and assessed.

Since teacher education programmes are formulated in response to the curriculum that the pre-service teachers would need to be *au fait* with when they start teaching in schools, it therefore makes sense for the pre-service teachers to be competent in GIS theory and practical applications. However, the introduction of GIS into the higher education curriculum has faced similar problems to those of schools. The Draft Report (NSIF 2006) which emerged from a workshop on GIS skills development in South Africa emphasised the need for academic institutions to standardise their modules so that a uniform training and assessment approach is adopted by universities. In addition, reforms in the school curriculum have an effect on the teaching and degree requirements of pre-service Geography teachers, together with a greater demand for in-service training of these teachers in GIS (Johansson 2003).

Of particular importance is the attention given to the assessment issues that such a change implies. Meaningful change in GIS education can be effected through curriculum, assessment and teacher learning (Coulter 2003). This author argues that GIS-enhanced inquiry lends itself well to the development of tangible artefacts such as maps and graphs that show student understanding (Coulter 2003: 6). He suggests alternative assessment methods that are strongly based on pedagogic content knowledge. He cites the example of teacher training in 'watersheds', where GIS spatial analysis was essential to understanding this topic. This demonstrated the need for GIS as an essential learning tool. Other alternative methods include long-term endeavours such as the development of GIS Leadership Institutes: "These Institutes are designed for teachers experienced in using GIS with students who are looking to develop advanced skills in both GIS applications and pedagogy, to build on their existing practice" (Coulter 2003: 10).

In South Africa the theoretical and practical teaching and assessment of GIS within the social, political and historical context is best understood within the critical social paradigm. This next section examines social critical theory, and its relevance to GIS teaching and assessing is discussed.

Social Critical Theory

Given its historical setting and rural location, the School of Education at the University of Limpopo collectively decided to use the critical social paradigm as the basis of its conceptual framework (School of Education 2009). This implies that teaching and learning of pre-service teachers incorporates the basic principles of critical social theory. Critical social theory is a multidisciplinary framework with the implicit goal of advancing the emancipatory function of knowledge (Leonardo 2004). Critical theorists attempt to create a link between theory and the actual lived experiences of people. Although Dewey is credited with the development of critical social theory in education, according to Giroux (1988) it is Freire who argued that the teacher should be seen as a transformative intellectual and a cultural worker. According to Leonardo (2004: 12), "In quality education, criticism functions to cultivate students' ability to question, deconstruct, and then reconstruct knowledge in the interest of emancipation."

Crucial to this study is the link between theory and practice that critical social theory advocates. Leonardo (2004) argues that critical social theory encourages the production and application of theory as part of the overall search for transformative knowledge. Theory is seen as less important than the practical (Freund 2009). Teachers see their work as being informed by experience rather than theory, causing them to develop a greater sense of themselves as classroom practitioners (Hargreaves 1984). In relation to GIS and the work of teachers, critical social theory is relevant because it locates the theory of GIS teaching and assessment with the practical implementation of GIS.

In South African rural learning platforms where the use of technology is limited, the social issues around technology education are pertinent. Lack of the relevant GIS technology implies that assessment is limited in such contexts. The next section examines assessment of knowledge and use of GIS software in assessment.

Assessment of Knowledge

When assessing knowledge, mixing two or more practical or theoretical interests results in assessment that is richer and more multidimensional (Brookhart 2004). Assessing knowledge using software systems is common practice and is associated with numerical scores and standardised tests. Falmagne et al. (2006) argue that the result of an assessment consists of two short lists of problems, which may be labelled: 'What the student can do' and 'What the student is ready to learn'. GIS software is ideal for this type of assessment as it allows users to create their own 'sets of knowledge' using the existing information found in various databases. In addition, pre-service teachers' thinking about the learning involved in using GIS software practically together with the assessment implications is embedded in the way they view the use and availability of GIS software. This has implications for the rural schools where they conducted their practice teaching and where they are most likely to teach in the future. According to Simon et al. (2010), the intersection of measurement, psychological and social theories continues to impact on the decision-making process in assessment.

Given the political, social and historical background of education in South Africa and the nature of assessment within such a context, this article now focuses on the research conducted on the training and assessment of pre-service teachers in the use of GIS software.

METHODOLOGY

This study was conducted with a group of third-year Geography Education students at the University of Limpopo in the first semester of 2011. There were 38 students in the sample, all of whom were training to become Geography teachers. Their exposure to GIS was minimal since they had not previously studied GIS at school, given that it was only introduced in 2006. Their first exposure to GIS was in their second year of study in Geography Education. One section of their content geography module contained theoretical aspects of GIS. All of the students were computer-literate. They were taught GIS applications using ArcView 9.2. ArcView is the GIS software package developed by the international company ESRI, and contains all the necessary maps, teacher and learner resources that make possible the teaching of GIS.

The students were taught the basic applications using the software for eight lessons of 45 minutes each, totalling 6 hours. In each lesson a different skill was taught; for example, creating maps, retrieving stored maps, database queries, overlay operations and buffer operations. The process involved reinforcing the previous skills taught before a new skill was introduced. The skills taught were exactly the same as those that they will be required to teach in schools, and the same software package is also used in the schools.

After these lessons all 38 students were asked to fill in a questionnaire on the training process, their competency in map drawing, and their self-assessment in the form of reflection on the learning process. The second data collection method employed was a practical assessment test on the skills taught. The questionnaire and test were quantitatively analysed and the findings are presented below.

RESULTS

Training in Use of GIS Software

The results indicate that the majority (25, or 66%) of students found the GIS software easy to understand, probably due to the fact that all of the students were computer-literate. Although 34% (13) students found the software difficult to understand, this figure would most likely decrease with more exposure to the software, as illustrated in Figure 1. Figure 1 shows the amount of training that students required (in terms of number of lessons) before they could easily work with the ArcView programme. After five to seven lessons, more students could work easily with the programme; one student said: “The more we work with the programme, the easier it becomes because we are computer-literate and all we need is practice and understanding of the skill”.

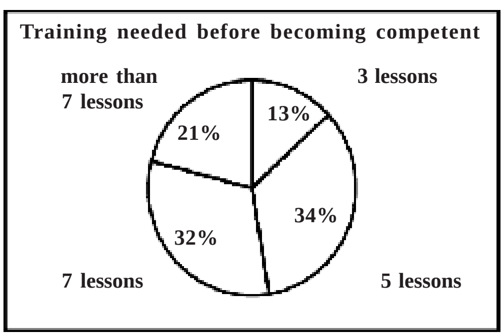

Fig. 1. Training needed before becoming competent

The students recognised the need for training in GIS - 68% of them stated that you cannot be self-trained. The reason for this is that some operations need explanation and others depend on mastery of basic skills such as map retrieval and overlay operations. Basic terminology also needs to be understood first, and navigation through the program must be mastered. In addition, 74% were of the opinion that Geography teachers in schools will not be able to cope with the kind of GIS training that they were exposed to. Again, basic terminology used and navigation through the program together with an explanation of the operations will have to be taught first before expanded use of the program is possible. Once the initial skills are mastered, teachers will be able to perform more complex operations.

Competency in Map Drawing

Of all the students surveyed, 89% claimed to have basic competency in GIS software. In addition, the results revealed that students were competent in basic operations like creating maps and reports, retrieving stored data, compiling geographic data from a variety of sources, designing and updating a database and entering new map data. Table 2 reflects the students’ responses concerning their ability to perform basic GIS functions: 66% were able to create maps and reports, 92% showed competency in retrieving stored maps, 82% were able to compile data from a variety of sources, and 66% were able to enter new map data. The skill of designing and updating a database was not yet mastered, and only 21% of respondents had these specialised skills in computing (that teachers may not possess). Finally, 79% of the students were confident that they would be able to teach learners to use the ArcView 9.2 software, by virtue of their mastery of the basic skills in using the ArcView software as well as some complex operations (Fig. 2).

Table 2: Basic GIS functions that were mastered

Question	*% Yes*	*No. (N = 38)*
1. Can you create maps and reports?	66%	25
2. Can you retrieve stored maps?	92%	35
3. Can you compile geographical data from a variety of sources?	82%	31
4. Can you design and update a database?	21%	8
5. Can you enter new map data?	66%	25
6. Will you be able to teach learners to use this software?	79%	30

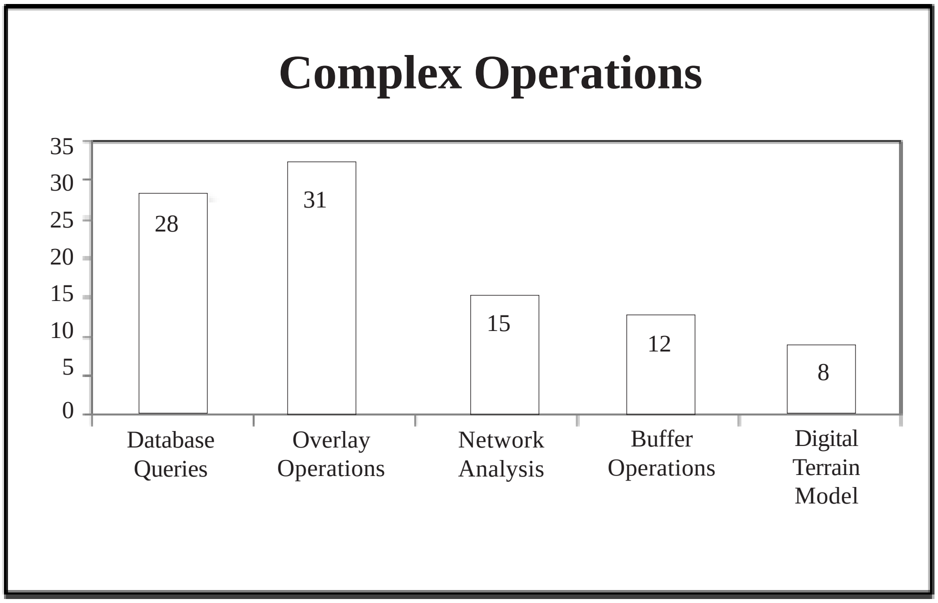

Fig. 2. Students' mastery of complex operations

Self-assessment: Students' Reflections on Their Learning

Students' reflections on their learning during the GIS training showed that 76% were totally confident in their ability to use the GIS ArcView 9.2 software. In comparison, with point and line data the majority (89%) felt that area data were the most difficult to work with. Interestingly, students were undecided about the necessity for Geography teachers and learners to master the use of GIS computer-based programs. The reason for this could possibly be that rural schools do not have the necessary technology to implement the teaching and learning of GIS practical applications. Finally, a staggering 92% of respondents were of the opinion that they will not have the opportunity to practice using GIS software in schools. This is attributed to the fact that these students know the conditions that prevail in the surrounding schools, since they were learners at these schools a few years ago and also did their pre-service training there.

Results from the Practical Assessment Task

After the initial training period of eight lessons the students were given a practical assessment task which they had to perform using the ArcView 9.2 program. The assessment task included a variety of operations that reflected their mastery of different skills. Overall, all students could perform basic operations, retrieve stored maps, conduct map overlay operations, scan data and make database queries. They showed average mastery of skills in compiling data from a variety of sources, digitising of data, projecting spatial data to the same projection (this is a pre-processing skill), correcting digitised and scanned errors, and removing irrelevant information.

DISCUSSION

GIS is taught and assessed at higher education institutions in a very structured manner. This means that the content is fixed and set out in a course outline which is approved by the national accrediting body. This includes assessment of use of GIS software for the practical component. However, in teacher training faculties the geography in content modules is vast and includes all sections of the Geography school curriculum. GIS is only a small section of this curriculum. This means that GIS content is not assessed in detail. This has implications both for the teaching and assessing of the section on GIS. As this article discussed earlier, given the wide-ranging uses of GIS in business, Government and the environment, it makes sense for GIS to feature more prominently in the school and university curriculum.

The integrated approach to using GIS will not be possible if the exposure is only for Grades 10 - 12 Geography learners for a total of 14 hours over 3 years. The short space of time allocated to GIS in the school curriculum corresponds to that allocated in the university content modules for Geography. In order to adequately prepare teachers to teach the section on GIS effectively in schools, more time will have to be allocated to this section during teacher training. This negates the intention of developing a national GIS strategy for South Africa.

From the results of this research conducted among pre-service Geography teachers, it can be concluded that more exposure to GIS content and assessment will positively influence both the practical and theoretical training of these teachers. With a teaching force that is trained and equipped to teach GIS, all that is needed are the *resources* to teach and assess GIS at schools. In the case of South Africa, therein lies the problem. While the new curriculum addresses the content issue (albeit superficially), the resources available in most schools are not anywhere close to making practical implementation and assessment of GIS skills possible. Rural schools are most affected by this situation. Limpopo is largely a rural province - and therefore these skills inculcated in pre-service teachers will probably lie dormant.

The results obtained from the questionnaires corroborated the results of the assessment task. Pre-service teachers coped well with basic GIS skills, but did not fare very well with complex GIS operations that involved different sources of data. This can be attributed to the amount of time spent acquiring complex GIS skills. Less time was spent on the complex activities, and more on basic GIS skills, which were repeatedly reinforced during training and assessment. The amount of training received in the relevant skills was directly related to their performance in the assessment task. The basic GIS skills were taught and repeated in the first seven lessons, and the corresponding results from the assessment tasks showed 100% competency in performance of basic GIS operations, retrieval of stored maps and conducting of map-overlay operations, together with 82% competency in database queries. Overall, the pre-service teachers performed better in the assessment tasks that required basic GIS competency. It can therefore be concluded that more training of a complex nature is required in order for them to perform better in the assessment tasks.

CONCLUSION

Considering the widespread use of GIS applications in many careers in the world of work, all students at universities training to be Geography teachers should be exposed to GIS, and in particular to GIS software. This can be taught and assessed in Computer Literacy classes as well as content modules in Geography Education. In higher levels of pre-service teacher training, training and assessment in more complex operations is essential. Assessment of GIS skills should also be linked to the available GIS software.

RECOMMENDATIONS

Firstly, the GIS component of Geography for pre-service teachers should be extended into a full module with practical assessment tasks. The only way to increase the number of teachers trained in the use of GIS software is to make the use of this software compulsory in pre-service training of teachers. It can be introduced as a component of Computer Literacy. Secondly, advocacy and awareness of GIS career paths must filter down to learners in schools, so that they are able to plan careers in the field of GIS. Thirdly, in-service training of teachers in GIS needs to be widespread and should incorporate use of GIS software by creating relevant practical assessment tasks. Finally, it is recommended that schools within a 20 km radius of the University of Limpopo be grouped into workable clusters, so that the university can provide GIS support to teachers teaching Geography in these schools.

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