Paper-Based GIS: A Practical Answer to the Implementation of GIS Education into Resource-Poor Schools in South Africa

Gregory Breetzke, Sanet Eksteen, and Erika Pretorius

Abstract

Geographical information systems (GIS) was phased into the geography curriculum of South African schools from 2006–2008 as part of the National Curriculum Statement (NCS) for grades 10–12. Since its introduction, GIS education in schools across the country has been met with a number of challenges including the cost of purchasing the hardware and software required to elucidate the basic concepts of GIS to learners. This article examines the introduction of GIS education in schools in South Africa. The development and distribution of a paper-based GIS educational package for resource-poor schools in the country is also highlighted. Preliminary educator and learner evaluations of the paper-based GIS package are discussed and the broader learning opportunities and benefits associated with flexible teaching mechanisms are examined.

Key Words: *South Africa, geographical information systems (GIS), schools, paper GIS, education*

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Introduction

Geographical information systems (GIS) is an exciting and fast-growing tool that holds a lot of potential for South Africa. GIS can be defined as a system for capturing, storing, analyzing, and managing data and associated attributes that are spatially referenced to the Earth (Longley *et al.* 2005). A system typically comprises hardware, software, geographic data, and personnel designed to manipulate geographically referenced information in order to achieve a stated objective. Through GIS analysis researchers in a variety of disciplines are able to better examine geographic patterns in their data and investigate possible spatial relationships between features of interest. Internationally GIS is one of the fastest growing industries with more than 170,000 people in the United States currently employed in the geospatial information industry in government, academic, and commercial sectors (Fazekas 2005). Worldwide GIS revenue from software, hardware, services, and data products exceeded $3.6 billion in 2006 (Daratech Inc. 2006), with revenues from GIS software vendors comprising more than half of the total. From an education perspective, GIS and its related techniques and methods has "helped open [sic] Geography's door" (Getis 2008, 4) with educators noting the ability of the tool to progress beyond traditional school-based geography and spatial problem solving (Bednarz and van der Schee 2006). GIS is envisaged as an invaluable resource for use in extending a learner's understanding of geography as it allows for the visual illustration, and manipulation of central concepts of the discipline.

The South African Department of Education (DoE) has not been oblivious to the rapid growth of GIS both locally and abroad. Indeed, GIS was listed as a "skill to be acquired" in the National Curriculum Statement (NCS) for geography in 2003 (South African Department of Education 2003, 10) although its actual inclusion in the curriculum was only phased in from 2006–2008. Anecdotal evidence suggests that the recent introduction of GIS in schools in South Africa has been problematic. Among concerns researchers note a lack of funding, and infrastructure in schools (Nxele 2007) as well as a lack of any theoretical grounding and practical experience in using GIS by educators (Zietsman 2002). This article investigates the introduction of GIS education in schools in South Africa, and identifies a number of challenges when attempting to implement computerized GIS teaching methods in technologically disadvantaged countries. In doing so the article highlights the development and distribution of a manual paper-based GIS system for use in teaching GIS in resource-poor schools in South Africa. The question posed is: can GIS be successfully taught in developing countries such as South Africa where technological and bureaucratic barriers so frequently impede the learning process?

GIS in South Africa

Despite lagging several years behind more-developed countries, GIS has developed along similar lines in South Africa (Schwabe 2001). The initial use of the technology lay in the environmental field before being discovered in the 1990s by larger metropolitan areas and municipalities that saw the value of GIS for managing their information and infrastructure. The availability of large-scale population and environmental datasets coupled with the proliferation of open source desktop mapping systems has resulted in GIS becoming a fast-growing industry in the country. The technology is currently being utilized by a number of key role players in South Africa including specific central, provincial, and local government departments, semiprivatized government institutions, as well as by a growing number of consulting firms and universities. From a governmental perspective, the key role players in the GIS industry are the Chief Directorate: Surveys and Mapping and the Chief Surveyor-General of South Africa. These state institutions are tasked with driving the overall growth and development of GIS in South Africa and currently play a vital role in providing a basic geospatial framework for data (Zietsman 2002). Other government departments provide ancillary data as part of their line functions, including the Department of Water Affairs and Forestry (DWAF), the Department of Agriculture (DA), and the Department of Environmental Affairs and Tourism (DEAT). Other key role-players include semiprivatized institutions such as the Council for Scientific and Industrial Research (CSIR), the Human Sciences Research Council's (HSRC) GIS Unit, the Institute for Soil, Water and Climate (ISWC), the Council for Geosciences, and the Satellite Application Centre (SAC). These institutions are all directly involved in the provision of GIS data or products based on their relative expertise in a variety of disciplines. In the private sector a plethora of GIS consultancies and suppliers have emerged to provide a range of GIS products and services to public and private sector clients. Specializations abound in various sectors including mining, industry, transport, tourism, agriculture, conservation, commerce, and water. The added popularity of mobile phone networks has also allowed consultancies to make their GIS solutions available from mobile phones as well as to develop specific mobile applications that utilize their geographical information. From an educational standpoint most universities in South Africa offer a GIS degree or include substantial GIS components within a related degree or diploma. South African tertiary institutions have historically adopted curricula based on the adaptations of those developed in North America and Europe (Zietsman 2002), although most institutions are currently developing their own GIS curricula to suit their particular study program. Final key role players in the GIS industry in South Africa are nonprofit organizations (NPOs) such as the Geographical Information Society of South Africa (GISSA). GISSA was formed in 2000 and aims to create a national identity for GIS in South Africa, as well as to protect and promote the interests of the geographic information (GI) community. Among its more recent accomplishments are the creation of a standards generating body (SGB), which is currently tasked with the establishment of GI unit standards for the country, and the standardization of geographic information science (GISc) qualifications across the country to allow for a GIS graduate to be professionally registered at the South African Qualification Authority (SAQA).

Despite the rapid growth of GIS across South Africa, its introduction in the South African school syllabus has not been as forthcoming. The curriculum for GIS was phased in incrementally and systematically over three years: into grade 10 in 2006, grade 11 in 2007, and grade 12 in 2008 as part of the geography curriculum. At the grade 10 level, the learner is taught the general concepts of GIS as well as the geographical concepts that form part of the technology such as entity types, scale (large versus small), and resolution (spectral and spatial). At the grade 11 level, the learner is taught the functional elements of GIS including data acquisition, satellite remote sensing as a digital data source, preprocessing and data processing. At the grade 12 level, which is the final level of schooling, the learner is taught additional functional elements of GIS including data management, data manipulation and analysis, and spatial analysis, product generation, and application. At the completion of schooling, the learner is expected to be competent in geographical numeracy through "applying GIS procedures and spatial statistics" (South African Department of Education 2003, 13). While it may be too early to thoroughly evaluate the introduction of GIS into schools in South Africa, anecdotal evidence suggests that a number of technological and bureaucratic challenges need to be overcome before widespread GIS education can be achieved in the country.

Challenges to the Successful Implementation of GIS in Schools in South Africa

The educational challenge for GIS in South Africa lies in trying to establish an environment in which the technology can be adequately taught. Kidman and Palmer (2006) identify three main impediments to the successful integration of GIS within schools that can be considered for GIS education in South Africa.

Money

Perhaps the biggest impediment to the successful implementation of GIS in schools in South Africa is the lack of funding and financial resources. The introduction of computerized 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. While the problems of funding GIS education in schools is relatively widespread (see Britton 2000; Bednarz and van der Schee 2006; Kidman and Palmer 2006), the situation is exacerbated in South Africa when one considers the country's recent political history. Segregationist education policies introduced by the Nationalist government during apartheid—notably the Bantu Education Act of 1953—resulted in the skewed distribution of financial resources in favor of former whites-only schools and to the detriment of black[1] schools. At the peak of apartheid, schools serving white learners had more than ten times the funding per learner than schools serving black learners (Fiske and Ladd 2005). As late as 1994, the amount spent per learner in white schools was more than two and a half times that spent on behalf of black learners. The result at the beginning of democracy was a shortfall of 29,000 classrooms in black primary schools and a shortfall of 14,000 classrooms in black secondary schools throughout the country (Nicolaou 2001). The shortage of classrooms was only part of the facilities problem as the majority of black primary schools had no electricity, 25 percent had no access to water within walking distance, and 15 percent had no sanitation facilities (Fiske and Ladd 2005).

The dawn of democracy initiated a pursuit of race-blind policies in both the funding and structure of public education by the newly elected African National Congress (ANC). The ANC sought to redress the policies of racial inequity in education through the introduction of a battery of laws including the 1995 White Paper on Education and Training, and the South African Schools Act (SASA) of 1996. The initial achievements made by the ANC government to fashion a racially equitable state education system were substantial and a number of their accomplishments are outlined in the *School Register of Needs Survey* conducted by the DoE in 2000. The results of the survey indicated significant advances in the provision of electricity, computers, and telephones in schools throughout the country from 1996 to 2000. It is discouraging to note, however, that despite these advances almost 90 percent of schools in the country still did not have computers in 2000. In addition, 80 percent of schools had no functioning libraries. More recently a study in the Eastern Cape Province of South Africa by Nxele (2007) highlighted the fact that 41 percent of schools in the province *still* do not have electricity and only 48 percent of secondary schools have computers. Contrast this with the over 1,900 U.S. high school classrooms that have a desktop GIS (Baker 2005), and it becomes increasingly evident that South Africa is still some way off technologically to establish a suitable environment for GIS education.

Support

Much prior research (see Bednarz and Ludwig 1997; Alibrandi 2001; Baker 2005) has shown that a lack of support is an additional factor impeding the widespread adoption of GIS in schools. Kidman and Palmer (2006) outline 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. Support from the school leadership is important to ensure that funds and facilities are available for the development and sustainability of the GIS program in the school. Additional support from those members of the school community not directly involved in teaching GIS is also vital and very much dependent on the benefits they perceive GIS can offer the school as a whole. Support from local tertiary institutions offering educator-training programs is also of paramount importance. This support should involve not only the training of educators in the basic hardware and software identified for use in the classroom but also the development of GIS curriculum support materials. Structured support from government and industry in South Africa for GIS education in schools has been forthcoming but has been largely restricted to the provision of a limited amount of educator-training or "professional development" programs. In South Africa, the training of educators or educator "professional development" (PD) forms part of the Continuing Professional Development for Teachers (CPDT) component of the National Policy Framework for Teacher Education and Development (2006). Under this policy all educators registered with the South African Council for Educators (SACE) must earn a certain number of PD points over a three-year cycle dependent on their developmental needs (South Africa 2007; Steyn 2009). Unfortunately, educators who wish to develop professionally by taking a program aimed at training them in GIS face a number of challenges. The first—and most poignant—is that no formal or regulated educator-training GIS programs exist publicly. This mandate has fallen largely on the GIS industry in South Africa with a number of private companies currently training educators and guiding the development of GIS educational material. Companies such as ESRI South Africa (Pty) Ltd[2] and Geomatica (Pty) Ltd have taken the lead in this regard and conducted a number of training courses aimed at teaching curriculum advisors and educators about GIS. Only a limited number of these workshops have, however, taken place and they have been restricted to the training of a handful of curriculum advisors and educators.

The reasons why the training of GIS educators in South Africa has shifted away from educational authorities and towards private companies are difficult to fathom. A possible reason could be the lack of individuals in public educational institutions in South Africa with specialist knowledge in GIS. A study by Steyn (2009) found that PD presenters in South Africa often lacked practical experience in the topics that they were presenting. Tardiness and a lack of fluency in English were other criticisms leveled at a large number of PD presenters. Moreover, Rust (2008) notes that those individuals that *are* attending GIS educator-training programs often lack the skills for imparting the knowledge they acquire to learners. Under such a malaise it is easy to envisage how commercial companies could sense an opportunity in the market. A second factor limiting the participation in GIS-related PD is that those programs that are offered to "teach the teachers GIS" are not compulsory but are classified as self-selected PD programs by the DoE. Self-selected PD programs are not funded (as opposed to compulsory programs, which are) and educators are required to pay for these programs themselves or apply for a limited number of provincial bursaries in order to **Q1**
take them. Moreover, these GIS educator-training programs are often located in major cities, which adds to the cost of educators attending them, particularly those educators coming from rural areas. So while the DoE had the foresight to include GIS in the National Schools curriculum, it has yet to institute sufficient measures to facilitate instructional and technical support. The support measures provided by government thus far have tended to focus on issues such as institutional vision and strategy and have not been linked to defined targets of improved learner performance (Fiske and

Ladd 2005). The establishment of an overarching support framework or curriculum plan embedded with the existing school structures would ideally improve the delivery of the new GIS component in schools.

Time

Other researchers (see Kerski 2003; Baker 2005; Chalmers 2006) regard a lack of time as the single biggest impediment to getting GIS into classrooms. This refers to the time required for educators to attend PD 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. Scrimshaw (2004) identifies the allocation of sufficient time for PD as *the* key element for educators to successfully integrate information technologies like GIS into their daily teaching and learning practices. In South Africa, the appropriate timing for the PD training of educators "is a big bone of contention" (Steyn 2009, 131). Typically, educators attending PD programs in South Africa do so on school holidays or in the afternoon following the conclusion of the school day. These times are however often considered unfeasible or unsuitable by educators as many are tired or involved in extracurricular activities. Paradoxically, these two options are preferred by school administrators since schools cannot afford relief staff if educators attend such programs during school hours (Steyn 2009). Related to the issue of time is the incentive for educators to take the time to attend PD programs. While there are a minimum number of PD points that an educator is required to obtain over a cycle of three years, the measures prescribed for failing to obtain these points is ambiguous, often resulting in a lack of desire and will on the part of educators to enroll in these programs. Indeed, the punitive measure that "teachers who do not achieve a minimum number of PD points over two successive cycles of three years will be accountable to SACE for such failure" (South Africa 2007, 20) is not only inadequate but encourages mediocrity.

The time constraints placed on educators in South Africa is further exacerbated by an ever-changing national curriculum framework. Educational transformation in the country has seen the adoption of a number of national curriculum frameworks including Curriculum 2005 (C2005), the National Curriculum Statement (NCS), and the Revised National Curriculum Statement (RNCS). These changes were necessitated partly by the need to take into account the knowledge and skills required to participate in a globalized society, and partly by the need to transform education and training to realize the aims of South Africa's evolving democracy. According to Jansen (1999), the revision in the geography curriculum postapartheid was indicative of a state seeking legitimacy following the national elections and had more symbolic than actual significance. Essential as these changes may appear in theory, their implementation in classrooms throughout the country has proven difficult in resource-poor contexts like South Africa and has resulted in a general lack of understanding by educators regarding the interrelationship between, and the "transcendence" from Curriculum 2005 to the NCS to the RNCS (Pudi 2006). The continuously changing curriculum in geography has also placed greater pressure on educators in South Africa to improve existing content, introduce new content (such as GIS), and strengthen continuity and progression in their programs under often time-strained circumstances.

Confronting the Challenges

One possible solution to the mounting challenges of implementing GIS education in technologically restrictive contexts such as South Africa is provided in the form of paper-based GIS education. The use of manual techniques to teach the basic concepts of GIS to learners is certainly not new. As early as the 1980s, a Manual GIS Approach to GIS education was proposed by Walsh (1988). In his research paper Walsh (1988, 17) familiarizes teachers with the "... relative simplicity of GIS implementation for investigations using both the manual analog and the automated digital GIS approach." Walsh outlines in detail the manual framework for GIS education with the aid of a case study. More recently Green (2001, 37) examined some of the ways in which GIS can be taught both with and without information technology, and highlighted the fact that "... some of the limitations of manual techniques makes them ideally suited to school-level education." In 2003 a special issue of the *Journal of Geography* investigated the various ways of implementing GIS in school classrooms. In that edition Baker and Bednarz (2003) bemoaned the lack of research in the domain of geographic information technology implementation in schools, particularly in the United States. Since then a number of studies have documented the implementation of digital GIS education in schools across the world (see Chalmers 2006; Kidman and Palmer 2006; Lam, Lai, and Wong 2009), but few studies have documented the implementation of analogue GIS education in schools, particularly in a developing world context. As outlined previously, while developing countries may face similar challenges as more developed countries in trying to implement and maintain GIS education in schools, their ability to confront these challenges does differ considerably.

Paper-based GIS in South Africa

The paper-based GIS initiative is the output of a project managed by ESRI South Africa (Pty) Ltd and supported by the Department of Geography, Geoinformatics and Meteorology at the University of Pretoria (UP) in South Africa. The members of the project team facilitated the introduction of GIS in resource-poor schools in South Africa through the development and distribution of a paper-based GIS educational package. The educational material contained within the package includes a 1:50,000 topographic map, a 1:10,000 orthophotograph, tracing paper, a ruler, colored crayons, adhesive, an exercise book for learners, and a handbook for educators. The paper-based GIS is packaged in a sealed A3 cardboard box and is currently being sold to schools at a price of R150 ($15) each. In terms of content, the handbook consists of seven practical lessons as well as an additional lesson on the GIS process developed by UP researchers. The lesson content includes the following:

- Lesson plan 1: Introduction to GIS
- Lesson plan 2: Definition of GIS, Components of GIS, and Uses of GIS
- Lesson plan 3: How GIS Is Represented Using Raster and Vector Data
- Lesson plan 4: Introducing the Concept of Data Acquisition
- Lesson plan 5: Digitizing Points, Attributes, Symbolizing, Labeling
- Lesson plan 6: Digitizing and Buffering
- Lesson plan 7: Answering a Ggeographic Question

The first four lesson plans in the paper-based package are aimed at teaching the basic principles and components of GIS to learners. The exercise book (for learners) and the handbook (for educators) are the two main tools of the paper-based GIS educational package that are utilized in these lesson plans. Two key questions are covered in lesson plan one. First, what are the key features of GIS? And second, what is the information age? In the lesson, the educator introduces the concepts of GIS and the information age, and generates discussion. Learners are required to write down the concepts that they are taught during the course of the discussion in their exercise books. Learners are then required to write a letter in their exercise books in which they discuss the impact that they think the information age is having on society and on themselves in general. In lesson plan two entitled "Definition of GIS, Components of GIS, and Uses of GIS," the educator introduces the concept of GIS as a link to map interpretation and as a skill for teaching geography. The main components that make up GIS are introduced and the many uses of GIS are identified. The purpose of the lesson is to generate discussion among the learners about this relatively new technology that they are being exposed to and to postulate on a definition of GIS. Learners are required to explain what GIS is and the different definitions that emerge from the learners are discussed. Using the 1:50,000 topographic map provided in the paper-based educational package, learners are then asked to identify the three basic entity types in GIS: points, lines, and polygons. If the topographical map provided covers an area that is known to the learners then they are asked to identify a series of features and landmarks. According to Liben and Downs (2003) spatial thinking begins with distinguishing and identifying spatial features of the real world on a map. By getting learners to identify points, lines, and polygons as well as known features on the analogue maps provided to them enables them to not only increase their map literacy but to generate mental representations of space.

The key question covered in lesson plan three is: How is GIS represented on a map? In the lesson the educator introduces the concept of map overlay using a hamburger analogy. Accordingly, each layer of the hamburger is emphasized as being important and plays a vital role in forming a complementary and complete hamburger. The educator then demonstrates the map overlay operation using the tracing paper provided in the educational package. There are two key activities for the learner in this lesson. First, learners are again asked to identify points, lines, and polygon features on the 1:50,000 topographic maps. Second, the learners are asked to draw a map of where they live using points, lines, and polygons and employing both raster and vector data structures. In this way learners engender a spatial understanding of their place in the world, as well as recognize how the real world can be envisaged as a model (a key concept in GIS). In lesson plan four entitled "Data Acquisition" the educator explains how GIS obtains its data and emphasizes the importance of scale, coordinates, and map projections in GIS. In the lesson each learner is given an orange and is asked to draw a map of the world on it. The concepts of scale, coordinates, and map projections are then taught to the learners using the orange as a teaching aid. For example, the difficulty in representing the real world in two dimensions is illustrated by attempting to squash the orange on a flat surface. The distortions in scale that occur during this process are identified and explained to the learners. Similarly, learners spatialize the world that is transcribed onto the orange as well as attempt to create different projections.

Lesson plan five involves getting the learners to understand how to approach a computerized GIS and how GIS can be used as a tool in geography. The educator introduces the concepts of digitizing, and discusses important cartographic principles such as symbolization and map annotation. It is at this juncture that the full contents of the paper-based resource are introduced and described to the learners. The key questions covered in lesson plan six are: How do we digitize? How do we construct layers? How and why do we buffer features? In the lesson plan the educator explains the concepts of digitizing, buffering, and map overlay to the learners and demonstrates these concepts using either a chalkboard or the tracing paper and crayons provided. In lesson plan seven, the learners have the chance to utilize and apply the knowledge they have acquired in the previous lessons to answer a geographical question using manual techniques. An example of such a lesson plan was developed at the University of Pretoria. Lambert and Balderstone (2000) see a lesson plan as being analogous to a play with a number of scenes that follow a clear structure and develop a plot (relating to the objectives). Similarly, the lesson plan developed by UP employs a narrative pedagogical strategy and uses multiple criteria analysis to assess the expansion possibilities of a small-scale South African business. In the lesson a hypothetical young man named Oliver is introduced as an entrepreneur in South Africa who sells comic books and wishes to expand his business into

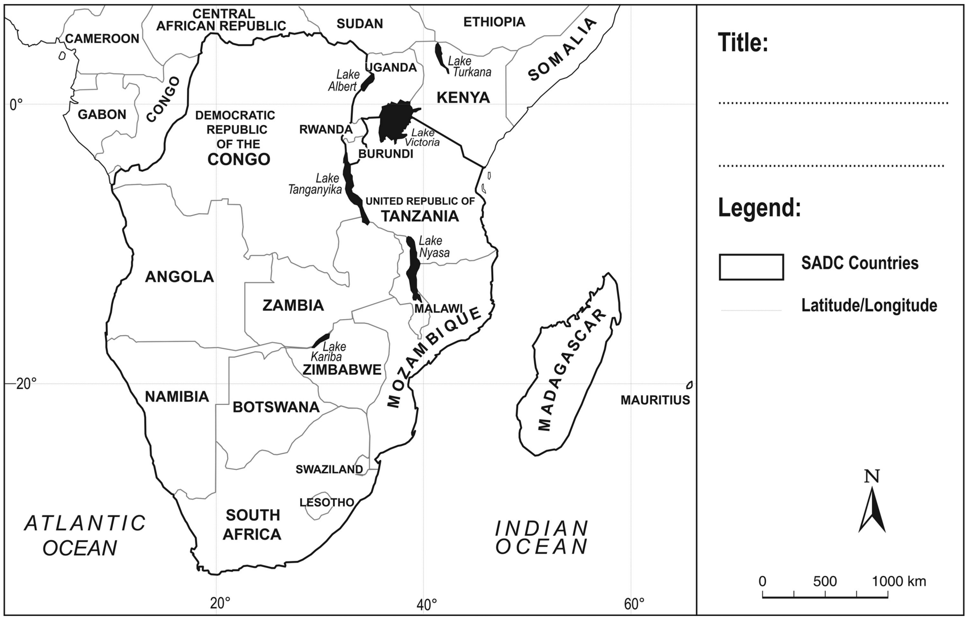

Figure 1. The South African Development Community (SADC).

the Southern African Development Community (SADC) (Fig. 1). Oliver wishes to identify which SADC countries are most suitable for him to expand into, and locate them on a map. Five fundamental GIS steps are followed by the learner— through the learning activities—in order to find a solution to Oliver's problem. First is the definition of the information product. In this step the learner is asked to formulate a research question as well as identify three criteria that he or she would like to satisfy when identifying suitable countries.[3] For example, one criterion could be that Oliver wishes to expand into countries that have a population density greater than twenty people per square kilometer. The rationale behind this step is to encourage the learner to conceptualize the broader problem that Oliver faces as well as to break down the problem into smaller manageable parts. In doing so, the learner also illustrates his or her ability to identify a methodological point of departure in the steps that follow. The second step involves designing the GIS model of reality. In this step the learner is required to identify what GIS data Oliver requires in order for him to satisfy the before-mentioned criteria. This process allows the learner to firstly seek out relevant data and secondly organize and display the data in a way that aids subsequent analysis and interpretation. Creating a representation of the real world based on user requirements is one of the fundamental planning operations in GIS (Longley *et al*. 2005). By encouraging learners to identify data relevant to their stated criteria not only challenges them to search and reject information but is also a useful way for learners to confront the often quoted computer science teaching mantra of "garbage in, garbage out (GIBO)."

The third step involves data acquisition and quality assurance. In this step the learner is provided with an incomplete attribute table containing financial and social information about SADC countries. The learner is required to identify missing data in the attribute table and fill in the blanks by using data in existing fields (e.g., population density (missing) = total population (provided) / area (provided)). After the completion of this task the learner is required to check the attribute table for completeness and correctness. The fourth step—data analysis—forms the analytical backbone of the lesson and involves the use of a number of core GIS techniques in order for learners to solve Oliver's problem. The first technique used is classification whereby the learner is required to group the given attribute data into two classes: those that satisfy a stated criterion (e.g., population densities greater than twenty people per square kilometer), and those that do not satisfy the criterion (e.g., population densities less than twenty people per square kilometer). On separate tracing paper and using different shading patterns, the learner then creates a separate map sheet for each stated criterion (Fig. 2). The second GIS technique—overlay—is then used to overlay the map layers on top of each other in order to identify those SADC countries in which all the stated criteria are satisfied (Fig. 3). This penultimate step in the lesson enables the learner to identify spatial patterns, relationships, and connections between different sets of geographic data. According to Aronoff (1989) the real power of GIS lies in its ability to integrate the analysis of spatial and attribute data. By using core GIS analytical tools such as classify and overlay the learner is taught to synthesize attribute and spatial data in a way that creates a meaningful observation. In the fifth and final step, the resultant map is created (Fig. 4). The rationale behind this step is to emphasize the importance of communicating the results of data analysis efficiently and effectively. Despite the growing popularity of GIS a limited amount of research has been done on the ability of the general public to read and make sense of geographic information (GI) being presented to them, particularly GI displayed online (Bayram and Ibrahim 2005). By introducing the basic principles of cartography at an early stage in a learner's development it is possible to develop a progression in learning that stresses the importance of map literacy all the way through to higher education. Throughout the lesson plan the learner is encouraged to understand the difference that *place* makes,

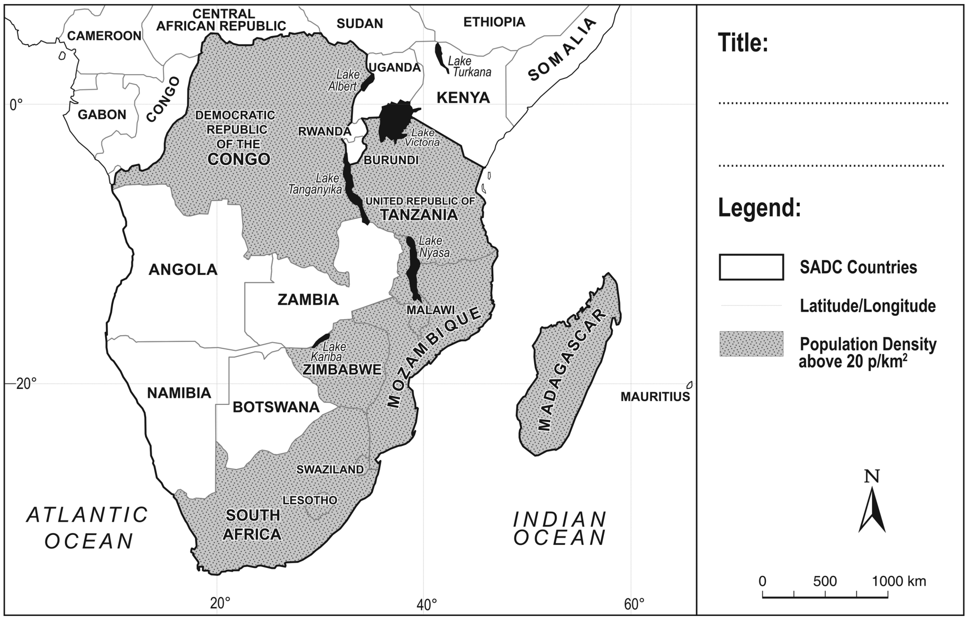

Figure 2. Classification—population density above twenty people/km^2.

firstly by identifying which financial and social characteristics are inherently similar between SADC countries, and secondly by determining what is distinctive and unique about each country. The resulting map of this paper-based GIS-based multicriteria analysis shows extended potential sites for Oliver to expand his comic selling business.

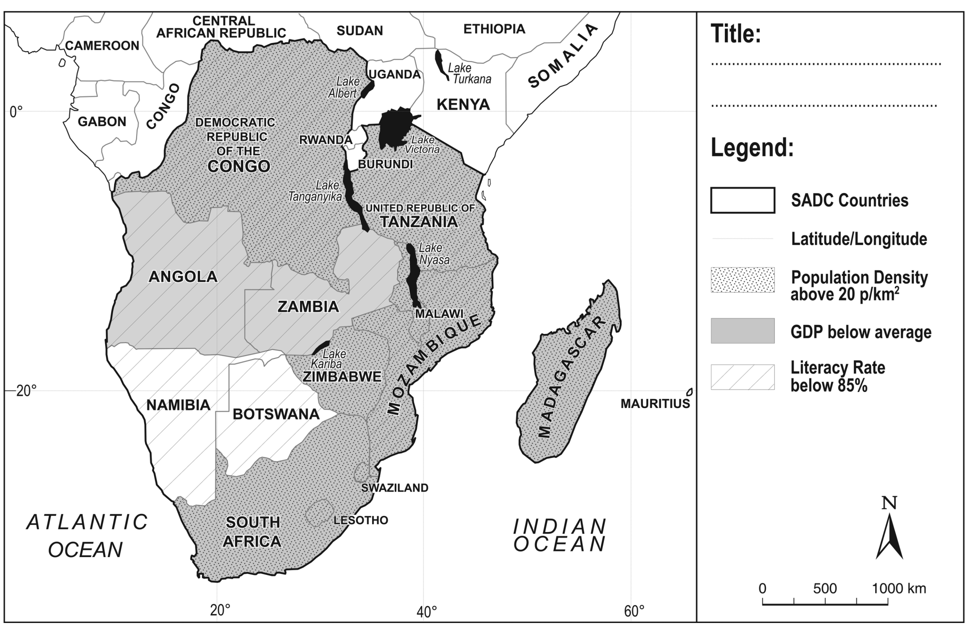

Figure 3. Overlay—selected SADC countries satisfying all three criteria.

An Early Evaluation

The paper-based GIS educational package was first demonstrated in December 2007 at a training session for twenty educators and curriculum advisors in the Eastern Cape Province of the country. The initial response to the package was favorable with a number of attendees remarking on the ability of the manual system to introduce the principles of GIS in a simplified and informative manner. In response to the increasing need for training educators and curriculum advisors in GIS, another three-day training course was held in January 2008 for approximately one hundred educators and curriculum advisors in Gauteng. The purpose of these training courses was to not only demonstrate the paper-based GIS package but to support educators' understanding of GIS in the National Senior Certificate geography syllabus. At the beginning of each course each educator was given a workbook containing the lessons and lesson plans that are compiled according to outcomes-based prescriptions. Each lesson was then described and demonstrated by a GIS support team.

It is difficult to accurately assess the impact and effectiveness of this instructional approach to teaching GIS in resource-poor schools in South Africa. Indeed, the distribution of the paper-based GIS package was initiated only in late 2008 while training in the package is currently optional for educators and/or curriculum advisors of these schools. Early feedback from learners regarding the effectiveness of this approach for learning has however been positive. Two schools were demonstrated the paper-based package in 2010 and learner opinions towards this pedagogy and its overall effectiveness were assessed using two separate measures. First, learners were surveyed using a transfer of knowledge questionnaire. Knowledge transfer is a primary goal of educators in virtually every discipline, and is the ability to apply information learned in one context to new contexts

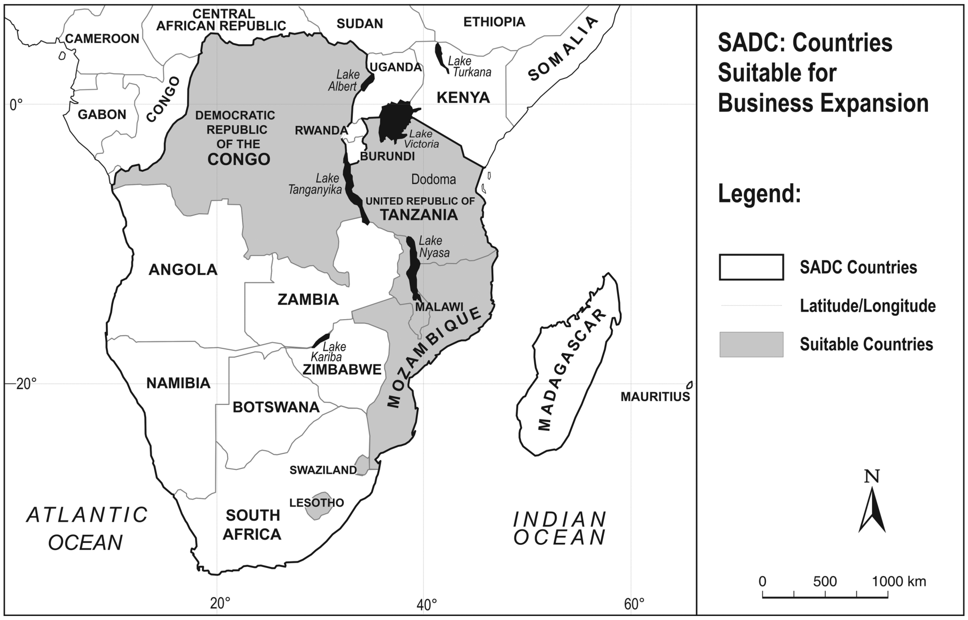

Figure 4. The final map indicating suitable countries.

(Devine 2006). The questionnaire itself consisted of two parts, the first part contained a set of questions designed to assess learners' spatial literacy and knowledge of GIS before the paper-based exercises were completed. Upon the completion of the exercises and after a considerable period of time, the second part of the questionnaire was given to the learners. It contained similar questions to the first part although a number of questions were added with the purpose of evaluating the learners' acquired knowledge applied to differing contexts. Second, learners were given an open-ended questionnaire in which they were asked to express their opinions on the paper GIS exercises and their thoughts of GIS in general. These two measures were initially applied to a pilot group of twelve grade 10 learners (15–16 year olds) to determine if the questions being asked obtained the desired information and if the questions were confusing to the learners. The results of the pilot study were positive with learners indicating that they liked the approach and found the lesson interesting. The group also clearly displayed an improved ability to transfer knowledge of GIS across various subject areas of geography including cartography. A number of challenges were experienced in the pilot group that were later attributed to the effect of language barriers as the group was very diverse with regard to their language and cultural background. A number of questions were revised and modifications made after the pilot session.

A second cohort of forty learners from a separate school was then surveyed using these two measures. The selected learners had some previous theoretical knowledge of GIS but—as is the case in most South African schools—had no previous access to computerized GIS. The results of the questionnaire before and after the completion of the paper-based exercise indicated that learners greatly improved their ability to think spatially and apply GIS concepts and principles in contexts outside the paper-based exercises they had previously completed. For example, in the first part of the questionnaire learners were given a map without the required map elements such as a north arrow, scale bar, and legend. The learners were then asked what essential information should have been added to the map in order to make it more useful and understandable. This was also expanded upon in the paper-based exercises. Later, learners had to create a new and unrelated map. Their maps were then evaluated by checking for all the required map elements. According to the National Academy of Science (2006), one characteristic of a spatially literate learner is the ability to adopt a critical stance to spatial thinking. In doing do, a spatially literate learner should be able to evaluate the quality of a spatial data product on the basis of its accuracy, reliability, and usability. Getting the learners to critique and subsequently create a map enabled us to not only gain an understanding of their map literacy but also allowed us to gauge their level of spatial literacy too. Similarly, in the first part of the questionnaire learners were asked to use thematic mapping to indicate economic and social trends among a group of countries. Later, learners had to indicate the location of various African global organizations on a map as well as trace member countries' boundaries. By getting learners to firstly identify countries of a certain membership and secondly group these countries on the basis of social similarity and/or geographic proximity, we were able to assess the second characteristic of a spatially literate student, namely that learners have a broad and deep knowledge of what spatial entities represent (National Academy of Science, 2006).

The results of the open-ended questionnaire assessing learners' opinions of the paper-based GIS package were extremely favorable. Approximately 93 percent of learners gave positive feedback on the exercises with most indicating that they found the exercises interesting and enjoyable. With the exception of one learner, all learners indicated that they had learned something new during the course of the exercises. Almost all learners found GIS innovative and believed that the technology will enhance their understanding of, and interest in, geography. As a caveat to this discussion it must be emphasized that the assessment of this instructional approach to teaching GIS in resource-poor schools in South Africa is ongoing. The results presented here reflect the opinions of two schools currently utilizing this approach and are therefore context-specific and preliminary. This fact notwithstanding, these initial results suggests that the paper-based GIS package *is* having a positive impact and does provide an adequate alternative to contemporary computerized GIS teaching methods.

Conclusion

Internationally GIS has long been regarded as an important part of geography education, both on its own and in association with other subjects such as information technology and environmental studies (Green 2001). Only recently, however, has South Africa taken measures to introduce the technology into its school syllabus with the technology now part of the geography curriculum in grades 10–12. GIS education in South Africa has proven to be fraught with difficulties, however, arising from a lack of money, time, and support from the broader school community to facilitate the integration of GIS within classrooms, particularly among the country's poorer schools. A solution to the challenges facing South African schools in implementing GIS education is provided in the form of a paper-based GIS educational package developed and distributed by ESRI South Africa (Pty) Ltd in collaboration with UP. The package is ideally suited to teaching GIS in resource-poor schools as it is cheap (money), easy to use (time), obtainable (support), and provides a basic introduction to GIS. While a computer is sine quo non for GIS education in much of the developed world, this study has highlighted the fact that in a developing world context, the manual GIS approach to education still has an important role to play.

Notes

1. The South African population is still officially classified into racial groups. "Black Africans" represent the descendants of west and central African populations. The "Indian" population group represent the descendents of south Asian populations. The "Colored" group comprise a mixed population including the descendents of the indigenous Khoisan population, imported Malay slaves, and people born out of mixed-race relations. The collective term "blacks" from this point onwards refers to these groups while the "white" population includes the descendents of European and other non-Indian Asians. While it might be expedient to employ the term "black" here, the group designated by the term should not be considered homogeneous.
2. ESRI South Africa is the sole distributor of ESRI software in South Africa and acted as the private sector partner in the introduction of this form of GIS education to schools in South Africa.
3. The learners are limited in the criteria they can select based on the availability of relevant data.

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