Journal of Geography Education for Southern Africa – (JoGESA)

NPO: 2017/035104/08

Volume 5, October 2020

The Journal of the Southern African Geography Teachers' Association (SAGTA) – ISSN 2517-9861

The educational research landscape on GIS integration and challenges – globally and in South Africa

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How to cite this article: Fleischmann, E. & C.P. van der Westhuizen (2020). The educational research landscape on GIS integration and challenges - globally and in South Africa. *Journal of Geography Education for Southern Africa* (JoGESA), 5: 19-41. DOI: https:doi.org/10.46622/JoGESA_5_2020_19-41.

Abstract

As Geographic Information Systems (GIS) have only been included in the curriculum in the last decade, many educators globally struggle to integrate GIS practice into their teaching strategies. Following the global trend, South African educators might feel ill equipped as they did not receive formal GIS training in a higher education institution. This paper highlights key global and South African challenges regarding GIS integration. To compare the challenges that South Africa faces with those experienced elsewhere, this mixed method study gleaned data from student educators (n=78) who completed a questionnaire regarding their GIS FET Phase education, followed by in-depth interviews with FET Phase educators (n=10) and two provincial heads of Geography for the Department of Basic Education (DBE). Results from this study indicate a clear global and national pattern of barrier categories.

Keywords: GIS, geography education, multimedia, instructional technology, teaching challenges

Introduction

The advent of Geospatial Information Systems (GIS) hailed an innovative era with a quest for international intelligence, global security, geospatial management, and decision taking in areas such as economics, environmental issues, political science, criminology, (MaKinster et al., 2014) and health sciences such as dealing with the COVID-19 pandemic. This wide field of GIS uses calls for a GIS skilled labour force. However, to effectively train GIS specialists in these various fields, calls for adequate GIS education. In other words, GIS education must first adjust to suitable GIS teaching methods so as to unlock the full potential of this application. The potential of GIS is generally expressed in its capability to manage geospatial information through the gathering, editing, storage, conversion, analysis and visualisation of geospatial data. Although Geography educators are on the whole fascinated by these GIS capabilities and learner-centred learning is the credo of the 21st century, GIS teaching often amounts to mere textbook GIS lecturing (Demirci, 2009). This inclination towards GIS textbook lecturing has largely jeopardized the quality of GIS education. Not surprisingly GIS education has gained global standing on various educational and political agendas (Höhnle et al., 2013, Kerski et al., 2013, United Nations, 2012)

This paper suggests that, due to the multiple categorical character of GIS implementation challenges, South African (SA) GIS Further Education and Training (FET) phase teaching is generally being neglected or, in some cases, not being implemented at all. To abridge these multiple challenges, we argue for the need of a standardised, curriculum-aligned multimedia GIS application. The aim of this paper is to provide a conceptual framework for dialogue between GIS application developers, the Department of Basic Education (DBE), the academy, GIS companies and educators to address current GIS teaching challenges, and to provide solutions within the GIS educational landscape in South Africa and possibly beyond.

GIS integration challenges: A global phenomenon

The paradox of educator fascination and equivalent application challenges is mirrored in that only 10% of Singapore's Geography educators have embraced GIS practice in their pedagogy (Liu and Zhu, 2008). Altogether only 18% of Turkish Geography educators utilise GIS, whereas only 33% of these educators are unfamiliar with GIS (Demirci, 2012, Demirci, 2009). In Germany, fewer than 33% of Geography educators have integrated GIS into their teaching (Höhnle et al., 2013).

These slow GIS adoption rates indicates that Geography educators are hesitant to integrate GIS practice. Reasons to this hesitancy might reflect their predicament of not knowing *where* and *how* to start with GIS practice integration (Hong, 2014). We argue that GIS practice education has stalled due to multi-categorical implementation challenges. Because of these multi-categorical challenges, countries on all levels of development grapple to integrate GIS practice. This trend is found in countries such as Austria, Canada, and New Zealand, while also noticed in countries such as Denmark, Finland, Japan and the UK, which are well equipped with GIS resources (Kerski et al., 2013). Reviewing the global educational GIS landscape closely, it becomes clear that although this outcome might be the same, GIS practice challenges differ (Demirci, 2011, Höhnle et al., 2013, Demirci et al., 2013). Scholars differ in their opinion regarding GIS practice adoption and development rates. While some researchers argue that the increased number of GIS research studies have been a catalyst for educational GIS implementation (Kerski, 2009, Kerski et al., 2013, Srivastava, 2013) others labelled the use of GIS practice integration within K-12 (Grade 12) schools in tandem with spatial cognitive skill development as "abysmal" and "challenged", with "small pockets of excellence surrounded by large oceans of ignorance" (Stylinski and Doty, 2014).

With the aim to provide a clearer picture of the GIS educational landscape, a summary of GIS integration challenges has been gleaned from literature. Table 1 represents findings of these challenges grouped according to key themes. During thematic content analysis, three key themes emerged: inadequate support from relevant authorities, educator barriers, and resources. Challenges related to receiving support from the Department of Education involved the curriculum and GIS practice, while those regarding educators could be divided into three sub-categories, lack of technological, pedagogical and content knowledge with regards to GIS; time constraints; and ignorance regarding GIS content. The resources category is subdivided into two subcategories, namely computer accessibility and lack of suitable software.

Key challenges (as tabled in Table 1) were:

- a deficiency of educator GIS conceptual knowledge and training in GIS (21 countries), which also suggests a deficiency of the educator's technological pedagogical GIS conceptual knowledge (GIS-TPACK),
- deficient appropriate GIS software applications and data for education (20 countries),
- deficiency of technology availability (16 countries),
- ·time constraints to implement and use GIS (13 countries)

Literature about the South African situation emphasised a deficiency of DBE guidance, time constraints and lack of suitable GIS software applications. Although computer accessibility did not emerge as strong within the South African context, this challenge did emerge within this study and is addressed later in this paper. In context with the global GIS educational landscape South Africa's educators' challenges in literature pose to be similar to a large extent.

Table 1: Synopsis of global identified challenges that prevent GIS integration into secondary schools

	Support	**Educator**				**Resources**		**Literature source**
Country	Lack of clear DoE guideline	Lack of GIS-TPACK	Bottom up & top down resistance	Ignorant about value of GIS	Time constraints	Computer accessibility	Lack of suitable GIS software & data	
Australia		X	X		X	X	X	(Wheeler et al., 2010, Kidman and Palmer, 2006)
Austria		X						(Jekel et al., 2012)
Canada		X	x*		X	X		(Huynh et al., 2012)
Chile		x*		X				(Muñ̃iz-Solari and Moreira-Riveros, 2012)
China		X				X	X	(Dong and Lin, 2012)
Colombia						X		(Salamanca and Vega, 2012)
Denmark						X	X	(Jensen, 2012)

Estonia		X			X		X	(Roosaare and Liiber, 2013)
Finland		X			X	X	X	(Johansson, 2003)
France		X						(Sanchez et al., 2012)
Ghana				X		X	X	(Oppong and Ofori-Amoah, 2012)
Hong Kong		X			X	X	X	(Lam et al., 2009)
Hungary		X						(Borián, 2012)
India						X	X	(Tiwari and Tewari, 2012)
Japan		X					X	(Ida and Yuda, 2012)
Lebanon		X						(Yaghi, 2012)
Malaysia							X	(Lateh and Muniandy, 2011)
Malta		X			X			(Attard and Schembri, 2012)

Netherlands		X				X	X	(Bednarz and van der Schee, 2006)
Norway		X						(Rød et al., 2010, Rød et al., 2012)
Portugal			X		X			(Mota, 2012)
Rwanda						X		(Forster et al., 2008)
Singapore					X		X	(Liu and Zhu, 2008, Yap et al., 2008, Liu and Tan, 2012)
South Africa	X				X		X	(Eksteen et al., 2012)
South Korea		X				X	X	(Kim et al., 2011, Kim and Lee, 2012)
Spain							X	(Del Campo et al., 2012)
Switzerland					X			(Stark and Treuthardt, 2012)

Taiwan					X		X	(Wang and Chen, 2013, Chen, 2012)
Turkey			X	X		X	X	(Demirci, 2011)
Uganda		X						(Ayorekire and Twinomuhangi, 2012)
United Arab Emirates		X		X		X	X	(Bualhamam, 2012)
United Kingdom		X				X	X	(Fargher and Rayner, 2012)
USA		X			X	X	X	(Baker, 2005, Baker et al., 2009, Kerski, 2003, Kerski, 2009, Milson and Kerski, 2012)
TOTAL	**1**	**21**	**4**	**4**	**13**	**16**	**20**	

GIS Education in the South African context

The inclusion of GIS in the South African (SA) education curriculum is in-line with the call from the United Nations (UN) towards GIS education (United Nations, 2012). Although GIS has been included in the Curriculum Assessment Policy Statement (CAPS), observers in SA differ in their views of GIS teaching (Fleischmann, 2016). Some critics have highlighted that a large percentage of schools are not only insufficiently resourced, but also that many educators are hesitant to employ available technology within their pedagogy. They argue that for these reasons, several schools have scrapped FET Phase Geography from their subject choices (Innes, 2012). This viewpoint is summed up by Mini's protestation that "GIS is tearing Geography asunder!" (Innes, 2012). Deducted from these findings, we argue that GIS educational policy developments have indeed overtaken the pace of GIS educational research and of suitable curriculum aligned GIS educational software packages in SA. The want for GIS research in the South African context is supported by the views expressed by Demirci (2008) and Fleischmann *et al.,* (2015), who advocates GIS education research to be contextualised in developing countries.

South Africa's digital divide

The South African Department of Basic Education (DBE) is in the unique position of having to cater for several very different groups of learners. In the first place, the large number of official languages (twelve – including South African Sign Language) inevitably creates a distinction between those learners who are well versed in English and those who are not. Low English literacy rates often hamper learners' conceptual understanding of abstract GIS terms and results in a dichotomy of extremes with fragmented academic community of disadvantaged and highly educated people. Economic differences further complicate matters and have a direct effect in the sense that while many learners enjoy the luxuries of private education, others do not have access to basic GIS resources such as computers. These factors, rather than age, play a substantial role in exacerbating and perpetuating the digital divide (Gudmundsdottir, 2010), a situation that is even evident among South African educators. When inadequate IT literacy is coupled with a lack of school community support (Breetzke et al., 2011), the scene is set for a flawed GIS teaching experience (Innes, 2011). In fact, most Geography heads of department (HODs) are experienced educators, who possibly feel inadequately equipped in IT and technological (GIS) matters. This digital 'ageism' amongst educators has created highly challenging opportunities for academia to face (Fleischmann, et al; 2017).

Category 1: Support – The curriculum and GIS practice. The CAPS document for GIS focuses on teaching and learning *about* GIS (*GISystems*) and insists on conceptual knowledge of general GIS concepts in Grade 10. CAPS also provides for flexibility of teaching of related geographic themes *through* GIS (*GI-Science*) in Grades 11 and 12. Furthermore, Grade 12 learners are required to be proficient in geographical numeracy, GIS methods and spatial statistics. Three different approaches to teaching GIS have been observed: first, teaching *about* GIS, second, teaching map skills *through* GIS, and lastly, teaching geographic or spatial concepts *through* GIS (Innes, 2012). However, the existing ambiguity about GIS teaching in the curriculum might be central to the delayed GIS practice in the FET Phase (Eksteen et al., 2012, Scheepers, 2009). It is therefore essential to reconsider GIS integration methodology together with the development of learning teaching support materials (LTSM) and applications which are aligned and standardised with regards to the GIS curriculum requirements (Eksteen et al., 2012).

Although it has been expected that GIS teaching would enhance the reputation of Geography within the school curriculum (Rød et al., 2010), observers differ in their views pertaining to GIS education in South African schools. The curriculum schedules limited time for teaching GIS. Due to the digital divide, educators are well aware that learners cannot be required to complete a GIS practical year-end exam during matric (Grade 12) (South Africa. Department of Basic Education, 2011). Logically, educators tend to focus on other Geographical themes when bearing in mind the upcoming year-end exam. Foreseeing these challenges, the DBE has called for “the collection and evaluation of existing digital, multimedia material that will stimulate all South African learners to seek and manipulate information in collaborative and creative ways” (South Africa. Department of Basic Education, 2004). Moreover, the DBE supports the generation of “new electronic content that is aligned with outcomes-based education” (South Africa. Department of Basic Education, 2004). The DBE dictates that “the research and development community must continuously assess current practices, and explore and experiment with new technologies, methodologies and techniques that are reliable and will support educators and administrators in e-Learning and e-Administration” (South Africa. Department of Basic Education, 2004). There is therefore clearly a drive from the DBE in its policies towards implementing GIS practice. A Geographical digital platform for downloadable GIS multimedia, interactive-GIS-tutor software and lesson plans may be the answer. This digital avenue might provide a viable answer to manage teaching and learning in an ever-increasing virtual self-directed learning environment.

Category 2: Educator. Literature refers to the educator as the key to GIS teaching (Chen, 2012). According to Innes (2011), the number of competent GIS educators has been declining, which poses a serious problem. One critical challenge for the Geography educator, to hone his/her GIS skills and prepare quality GIS lessons is time. To integrate GIS practice, time is needed to attend GIS workshops, to receive GIS software training and to master rudimentary GIS software. Moreover, additional time is also needed to load GIS software and solve hardware issues. Educators furthermore need time to prepare GIS practice lessons plans and to align their GIS learning teaching support materials (LTSM) accordingly. In addition, an already full FET Phase Geography curriculum competes with GIS for subject time. Furthermore, within a set school roster the Geography educator often needs to compete with the CAT educator for computer lab access. These reasons cause many educators to revert to textbook GIS teaching. The authors are of opinion that a pre-prepared Interactive-GIS-Tutor may circumvent most of these time issues.

Category 3: Resources. A determined effort is required to address the huge backlog of 88% South African schools that lack educational tutorial software (in all subject areas), (Blignaut et al., 2010). What further aggravates the situation is the lack of educational orientated organisations or companies, committed to developing digital material suitable for South African schools (Isaacs, 2007). Again, there is the need for a curriculum aligned plug-and play Interactive-GIS-Tutor that unlocks flexible teaching and learning possibilities also within the current COVID-19 lock down situation.

Methodology

A GIS teaching survey was undertaken among first-year Geography student educators (n=78) to evaluate their own GIS learning experience within the FET phase and to determine whether these South African students experienced the same GIS teaching challenges in comparison to the rest of the globe. Global GIS teaching challenges have been deducted through content analysis of literature. This was followed by in-depth interviews with educators (n=12) and correspondence with two provincial Heads of Education for Geography (n=2). Pseudonyms are used for educators and schools within this paper.

GIS teaching survey among first-year Geography student educators

The current study aimed to determine the extent of current Geography student educators' exposure to GIS during their FET Phase Geography classes. All the first-year B.Ed. Geography student educators of 2014 took part in the study (N=78) and it was found that 61 (78%) had Geography as a major for teaching at secondary school (Grades 10, 11 and 12) while 17 students completed Geography as part of Social Sciences up to Grade 9. The 78 students were representative of 58 secondary schools in nine provinces from across SA. In addition, 12 FET Phase Geography educators from rural and urban areas of KwaZulu-Natal were selected for in-depth interviews.

Instrumentation, data collection and analysis procedure

Whilst investigating the level of GIS practice in FET Phase Geography, and possible GIS teaching challenges, the following pragmatic mixed methods approach was employed:

> *A questionnaire consisting of 32 questions and based on a four-point Likert scale* was compiled to measure the extent and kind of GIS exposure within FET Phase Geography (the results are summarised in Figure 1, and the participants' viewpoints on GIS integration in schools are shown in Table 2). The internal consistency of this questionnaire was calculated by using Cronbach's coefficient alpha and the result was *0.790,* which implied an acceptable level of internal consistency.
>
> *Semi-structured educator interviews were conducted with 12 Geography FET Phase educators and the data obtained was analysed using Atlas.ti7™ software.* Deductive codes were gleaned from global literature on GIS education, and to contextualise this study, inductive coding was used through theme analysis, which emerged from the interviews.
>
> *Correspondence with two provincial Head of Education in the Geography department* was based on GIS implementation challenges as experienced from DBE's side.

Findings and discussion

Student educator questionnaire

Table 2 shows the results obtained from the student educator questionnaire. A high proportion (88.67%) of the 78 student educators indicated that they had undergone GIS theoretical training, while 3.33% stated that they had seen and used GIS on the Internet. A further 2% reported to have used Google Earth and 1.33% stated that they had seen GIS on a computer. Of this group students, 1% used web-based GIS while 3.68% declared that they had used other means of GIS during the FET Phase.

Table 2: Method of GIS education used in FET Phase during 2011-2013 (n=78)

	Form of GIS in School	*% Gr 10*	*% Gr 11*	*% Gr 12*
1	Only Theory; Only in the textbook; "Paper-based" GIS	86	92	88
2	Seen / used on the Internet	3	3	4
3	Saw it on a computer	1	1	2
4	GIS on a CD or DVD Rom	-	-	-
5	On Google Earth	3	1	2
6	Web-based GIS on the Internet	1	1	1
7	Worked with GIS on a computer	-	-	-
8	Worked on the software ArcGIS/ArcView	-	-	-
9	Did GIS on own computer	-	-	-
10.	Any other	6	2	3

Results from Table 2 confirmed the fact that exposure to GIS in the FET Phase Geography exists predominantly in theory only, with the use of a textbook or paper-based GIS. Moreover, we found it disturbing that none of the 78 Geography first-year students had ever used a GIS software application in school, and only a few students stated that, over the three-year FET Phase, they had actually *seen* GIS-related software on a computer (3.33%), on Google Earth (2%) or on the Internet (1%). As students from this cluster are representative of each province, it may be an indication that GIS practice has stalled. Although most (±74%) of the students knew *about* Google Earth and Google Maps, about 45% of them were *not really sure that they could actually use it*. However, although most of the students did not receive practical GIS education themselves, the first-year Geography student educators were overwhelmingly positive about the necessity of GIS integration in and application at school (see Table 3).

Table 3: First-year students' (2014) viewpoint on the use of GIS in schools (n=78)

Questions from the questionnaire	*1*	*2*	*4-point Likert Scale* *3*	*4*	*Mean*
1. Do you think GIS should be used for teaching Geography?	0	5	18	55	*3.7*
2. Do you believe that GIS can help with Geography teaching?	0	5	22	53	*3.6*
3. Will you use GIS when teaching Geography?	0	8	26	44	*3.5*
4. Will you use GIS frequently for yourself (own purpose)?	2	10	35	31	*3.2*

1 = *Not at all*, 2 = *Not really*, 3 = *Possibly*, 4 = *Yes*

As many as 55 of the 78 students (with a mean of 3.7 out of 4) felt that GIS should be used for the teaching of Geography at school, and more than 70% thought GIS could actually help with Geography teaching. Moreover, 70 students indicated that they would possibly or definitely use GIS when teaching Geography. Although these students had neither been exposed to nor used GIS at school, they did seem to value the teaching of it in school. This correlates with the viewpoints expressed by the 12 educators during the interviews. However, the students were divided in their opinion about the frequent GIS usage for themselves. A possible reason for this may be that they had not been exposed to the use of GIS applications during school Geography, which is experienced as a serious shortcoming in GIS education.

Interviews with FET Phase educators

During the interview analysis, data gleaned from the interviews indicated three key areas in the GIS teaching challenge: lack of support, educator barriers, and lack of resources. These three key areas were found to be prominent during the content analysis of GIS educational challenges globally (see Table 1). Although educators were positive about GIS inclusion in the curriculum, many of their comments indicated a gap between theory and practice in their GIS teaching. This trend mirrors that found in literature globally (see Table 1). Although, on average, educators are optimistic regarding GIS in the curriculum, the practical challenges that are experienced cause GIS education to remain largely theoretical. Ms Henley, a provincial head of the Geography department, stated: *…we do struggle with GIS like the rest of the country*. This GIS teaching struggle is reflected in the matric exam, where whole classes fail the GIS section. Ms Vuzi, a school educator commented: *…some of the educators do not teach GIS, because if you go for marking at the end of the year, you can see that these learners were not taught*.

The educators all approved the inclusion of GIS in the curriculum. This came as a surprise, as people are naturally inclined to have a negative attitude towards change. In an attempt to find the reason for the positive attitude towards GIS in the curriculum, despite the gap between GIS theory and practice, challenges were selected from the primary documents. The literature study informed us of global key GIS teaching challenges, but even more challenges emerged within the South African context. Analysis of the GIS teaching challenges revealed that because of the limited allocation of time for GIS teaching and as exam questions focus largely on GIS theory, educators revert to textbook GIS teaching. This may be a major reason why GIS practice has not permeated South African education, as confirmed in Table 1.

All the respondents nonetheless agreed that GIS practice is an important and vital element of the Geography curriculum. There were also some instances where some educators recommended that GIS should be included in the curriculum from the start of the senior phase (i.e. Grades 4-9 in the Social Sciences).

During the interviews conducted it emerged that educators are in desperate need of DBE guidance with regards to GIS teaching. Support from the DBE appears to be crucial to enhancing GIS teaching. Another lacking supportive aspect of DBE is the provision of suitable GIS learning teaching support material (LTSM), as was highlighted by Mr Green: *The Department needs to… comprehend and get together and make a plan to get material out to educators…* There is a need from the educators' side to receive more support for GIS teaching, as stressed by Mr Hinabar: … *the department hasn't done their bit of resourcing the schools in terms of computers and making sure that these programmes are running.*

Furthermore, many of the older educators did not undergo formal GIS training, and felt inadequately equipped to teach GIS. However, educators who attended GIS workshops did not find the workshops useful, as GIS was not a priority, leaving them with minimal guidance to sort through complex software, as indicated by Mr Snuba: …*we attended a workshop, a while ago, which we didn't learn much from…* Workshops offered by GIS specialists turned out to cater mostly for computer literate educators, as Ms Derricks, Head of the Department at her school, phrased it: *I always feel ill-equipped … I've been on a few courses … the people who presented it were extremely well-versed in GIS and I always feel as though I'm being left behind, as though I really don't grasp it…*

Yet, because of numerous GIS practice variables, it remains a challenge for the DoBE to provide the needed guidance pertaining to GIS teaching, as disclosed by Ms Norman, the Head of

Geography in one of the provinces: *I am struggling to ensure formal training to the educators ... most did not receive formal training… older educators struggle with the technology whereas the learners prefer technology. Educators need to be trained and software plays a vital role.*
Ms Norman's statement confirms the complexity of GIS teaching. The educator remains a crucial element in GIS teaching, especially with regard to GIS pedagogy, educator GIS knowledge, educator technology and time constraints. As workshops present a means of equipping educators for GIS teaching, these four aspects should be addressed in GIS educator-orientated workshops. All twelve educators who were interviewed found themselves ill at ease when teaching GIS.

Most of them considered themselves to be ill-equipped regarding GIS pedagogy, GIS knowledge and GIS technology. As Ms Duma explained: *…in the sense that at the moment I don't really want to [use GIS], because I feel it's a huge mountain, and I feel intimidated, because I don't know enough.* It emerged from these interviews that four types of educator knowledge (i.e. Technological Pedagogical Content Knowledge (TPACK)) were necessary: (i) GIS pedagogical knowledge; (ii) GIS content knowledge; (iii) GIS technology knowledge; and iv) Geographical conceptual knowledge. All these educators understood Grade 11 Geography concepts, which was perhaps why they wished to implement GIS practice to instil in learners an awareness of the importance of Geography in everyday life. In order to attain this goal, more issues emerging from the interviews and pertaining to the learners would have to be addressed, namely varying class sizes, with some classes in rural areas having large numbers of learners in one class; varying computer skills among learners; poor GIS teaching in Grade 10; and the wide variety of mother tongues.

In post-apartheid SA, schools started accommodating all cultures after 1994, and consequently learner differences regarding home context, language disadvantage, etc. became more apparent. Furthermore, apart from the fact that South Africa's 11 official languages differ widely, GIS 'language' is abstract and difficult to understand. Most local school children do not receive education in their mother tongue, which further hampers the conceptualisation of GIS terms. To effectively teach GIS to Grade 11 learners, the learners would require a good Grade 10 GIS basis. However, this is also not always the case, as remarked by Mr Snuba: *…what I notice with GIS, …some* [learners] *don't have a good foundation built up.*

Large classes pose a further challenge to GIS practice, according to Mr Snuba: *We were given some software, but our class sizes are 40, 45 …we don't have 45 computers.* Mr Snuba added also that huge classes expand learner difference and variety. Mr Green, an educator at Glenville High, stated that some learners had to wake up at 4:00 to catch a taxi from their homes, more than 80km away in a rural area, so as to be on time for school every day. As a consequence, they were tired in class, which influenced their attention levels. In contrast, however, it was our observation that this class was eager and motivated to learn as they had to make a greater effort to receive education. In comparison, we found the learners at Valken Hoërskool ill-motivated and digitally spoiled. Learners' varying computer skills also posed a major challenge, as alleged by Mr Hinabar, an educator at Houston High, a school situated close to shacks in a black township. Most of the learners were very poor, with no opportunity to acquire computer skills. Lack of these skills put further strain on the teacher who had to include both the 'haves' and the 'have-nots' in his classes.

The digital divide was clearly evident, as some schools were well equipped with state-of-the-art digital technology, while in other schools the educator was only supplied with a textbook. The lack of viable resources remains a significant challenge, further limiting the options of GIS practice. This deficiency of usable resources was mainly caused not only by the digital divide in the schools, but also in the learners' homes. This divide was responsible to further create negativity towards GIS learning, as admitted by Mr Snuba: *They have got first-hand information on GIS. Our ones over here, unfortunately, because of circumstances beyond our control, they shy away from the section … it's creating in the learners a sense of negativity.*

The main resources requirements were hardware and appropriate educational GIS software. Although some schools were furnished with a computer lab, in many cases the computers were outdated, lacking sound cards and sometimes infested with computer viruses. In most cases, the CAT/IT learners from Grades 10 to 11 made use of the lab. In large schools this sometimes caused conflict when the computer room had to be booked for Geography. Complex and state of the art GIS software packages aggravates the low-capacity computer problem, as highlighted by Ms Venter: *… We've tried QGIS, in the past, but then the computers have crashed.* Mastering the software also posed a challenge to the educators, as admitted by Ms Venter: *…regarding QGIS… I was doing the course; I was going like a Boeing… I thought I was quite a boffin. But then I couldn't remember …they said, you just play around with the programme. But then I deleted something…*

Upon investigating the reason for the privation of resources, the digital divide, as noted in literature, again became evident. Mr Snuba remarked: *Because they have the facility, it's a better resourced school, I think you know I'm right, …a better resourced, …here we are under resourced.* Mr Snuba also noted that many of their learners postpone paying their school fees indefinitely, due to poor economic conditions. Since all the schools in this study had access to textbooks, GIS textbook teaching was their pedagogical choice, even if they thought highly of the use of GIS technology. Complex and abstract general GIS terms in the Geography textbook are in many cases unfamiliar to second-language English learners. Mr Snuba elucidated this point clearly within his following quote: *… if you just ask what is data, they won't know… manipulation, they won't know. So how are they going to know what's data manipulation? ...we have a large number of second language learners…*

Within this study we found that the digital divide aggravated the situation, causing mounting frustration among both educators and learners. While all the educators were fascinated and enthusiastic about GIS practice, they reported that they were waiting for the DoE to provide clear guidance and resources. Because this was such a complex task, the implementation of GIS practice virtually stalled. Given this scenario, our study suggested that academia should provide guidance and support by designing and evaluating workable GIS packages and GIS integration frameworks. One such example is a study on an interactive-GIS-tutor framework proposed for FET phase Geography (Fleischmann, 2016).

The three categories can be analysed as follows: Support: The DoE needs to support educators by providing guidelines for GIS integration. Guidelines could inform workshop agendas, whilst these educator workshops could provide additional guidelines, as informed by the curriculum.

Educator competence: Bottom-up resistance from educators to GIS implementation is evident, especially with veteran educators who usually head their schools' Geography departments. Upon investigation, it became evident that it was not so much a matter of GIS not being valued, but rather that the educators involved felt insecure with regard to GIS technology and practice, which can be related to TPACK. The latter involves the kinds of knowledge (i.e. *technology knowledge*, *subject knowledge*, *pedagogical knowledge* and *GIS knowledge)* that an educator needs to practise effective pedagogy in a technology-enhanced learning environment. In addition to educators' inadequate competence and skills, numerous learner differences were found, relating to multiple home languages, large classes, computer literacy and visual orientation.

Resources: The resources needed in this context comprise of computer hardware and GIS software. The latter, however, is mostly complex and not curriculum aligned. The discussion above clearly indicates the need for a GIS software application to circumvent the major implementation challenges found in literature, whilst also addressing the educator's lack of *technology knowledge*, *subject knowledge*, *pedagogical knowledge* and *GIS knowledge*.

Three assertions were made based on the twofold discussion regarding the research question, namely: *To what extent do FET Phase schools use the Geographic Information System (GIS) in*

Geography instruction? and: *What main challenges do educators experience with regard to GIS practice?*

Assertion 1: All student educators who completed FET Phase Geography only received textbook/paper-GIS teaching at school and gained little or no experience of Google Earth. However, these student educators were all found to be very optimistic about GIS education.

Assertion 2: None of the 12 FET Phase Geography educators in this investigation employed GIS practice (software), although they all agreed that there was a need for GIS learner exposure.

Assertion 3: The main GIS teaching challenges emerging from the literature and reflected in this study can be divided into three main categories, namely a lack of support from the authorities; the educator as barrier; and a lack of resources.

Conclusion and recommendations

Due to the gravity of the digital divide, from which most GIS implementation challenges stem, GIS practice within the education system has come to a halt. This study indicates that none of the eight schools that formed part of the qualitative research component, and all of the 57 schools represented by the first-year student educators involved in the quantitative part of the study, previously employed GIS practice and they all reverted to textbook teaching to circumvent current GIS practice challenges. The research in hand is indicative that numerous South African educators, as is the case in the rest of the world, struggle to teach GIS appropriately in school. This research also indicates that there are significant challenges that prevent GIS practice integration. We found that most of the South African GIS teaching challenges correspond with global GIS teaching challenges, which account for the lack of GIS implementation at school level. As this slow and hesitant global diffusion of GIS practice into education remains a confounding and challenging issue, a self-paced interactive GIS plug-and-play tutor application might be the solution. Such an application has been developed by North-West University in an attempt to overcome teaching-learning challenges and demonstrate to be a feasible anytime-anywhere learning option that can support direct GIS learning and teaching needs. It is suggested that future research should firstly evaluate thoughtful GIS innovations against these major challenges in developing countries and secondly take note of some initiatives taken by Geography educators to overcome these challenges.

References

ATTARD, M. & SCHEMBRI, J. A. 2012. Malta: GIS and Geography teaching in the context of educational reform. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

AYOREKIRE, J. & TWINOMUHANGI, R. 2012. Uganda: educational reform, the rural-urban digital divide, and the prospects for GIS in schools. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

BAKER, T. 2005. Internet-based GIS mapping in support of K-12 Education. *The Professional Geographer,* 57, 44-50.

BAKER, T., PALMER, A. & KERSKI, J. 2009. A national survey to examine educator professional development and implementation of desktop GIS. *Journal of Geography,* 108, 174-185.

BEDNARZ, S. W. & VAN DER SCHEE, J. 2006. Europe and the United States: The implementation of geographic information systems in secondary education in two contexts. *Technology, Pedagogy and Education,* 15, 191-205.

BLIGNAUT, A. S., HINOSTROZA, J. E., ELS, C. J. & BRUN, M. 2010. ICT in education policy and practice in developing countries: South Africa and Chile compared through SITES 2006. *Computers & Education,* 55, 1552-1563.

BORIÁN, G. 2012. Hungary: GIS in natural science educator training. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

BREETZKE, G., EKSTEEN, S. & PRETORIUS, E. 2011. Paper-based GIS: A practical answer to the implementation of GIS education into resource-poor schools in South Africa. *Journal of Geography,* 110, 1-10.

BUALHAMAM, M. R. 2012. United Arab Emirates: building awareness of GIS in education through government and university outreach. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

CHEN, C.-M. 2012. Taiwan: the seed of GIS falls onto good ground. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

DEL CAMPO, A., ROMERA, C., CAPDEVILA, J., NIETO, J. A. & DE LÁZARO, M. L. 2012. Spain: institutional initiatives for improving Geography teaching with GIS. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

DEMIRCI, A. 2008. Evaluating the implementation and effectiveness of GIS-based application in secondary school geography lessons. *American Journal of Applied Sciences,* 5, 169-178.

DEMIRCI, A. 2009. How do educators approach new technologies: Geography educators' attitudes towards Geographic Information Systems (GIS). *European Journal of Educational Studies,* 1, 43-53.

DEMIRCI, A. 2011. Using Geographic Information Systems (GIS) at schools without a computer laboratory. *Journal of Geography,* 110, 49-59.

DEMIRCI, A. 2012. Turkey: GIS for educators and the advancement of GIS in geography education. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *Turkey: GIS for educators and the advancement of GIS in Geography education.* New York: Springer.

DEMIRCI, A., KARABURUN, A. & MEHMET, Ü. 2013. Implementation and Effectiveness of GIS-Based Projects in Secondary Schools. *Journal of Geography,* 112, 214-228.

DONG, P. & LIN, P. 2012. China: educator preparation of GIS in the national Geography curriculum. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

EKSTEEN, S., PRETORIUS, E. & BREETZKE, G. 2012. South Africa: teaching Geography with GIS across diverse technological contexts. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

FARGHER, M. & RAYNER, D. 2012. United Kingdom: realizing the potential for GIS in the school Geography curriculum. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

FLEISCHMANN, E.M-L 2016. A framework for interactive-GIS-Tutor Integration within FET Phase Geography.

FLEISCHMANN, E.M-L. & VAN DER WESTHUIZEN, C.P. 2017. The Interactive-GIS-Tutor (IGIST): An option for GIS teaching in resource-poor South African schools. *South African Geographical Journal* 99(1), 68-85.

FORSTER, M., MCCONNEL, T. & SCHILLING, M. 2008. Introducing GIS to K12 education in Rwanda.

GUDMUNDSDOTTIR, G. B. 2010. When does ICT support education in South Africa? The importance of educators' capabilities and the relevance of language. *Information Technology for Development,* 16, 174-190.

HÖHNLE, S., SCHUBERT, J. C. & UPHUES, R. 2013. What are the constraints to GIS usage? Selected results of a educator survey about constraints in the school context. *International Research in Geographical and Environmental Education,* 22, 226-240.

HONG, J. E. 2014. Promoting educator adoption of GIS using educator-centered and educator-friendly design. *Journal of Geography,* 00, 1-12.

HUYNH, N. T., SHARPE, B., CHARMAN, C. & TONG, J. 2012. Canada: teaching Geography through geotechnology across a decentralized curriculum landscape. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

IDA, Y. & YUDA, M. 2012. Japan: GIS-enabled field research and a cellular phone GIS application in secondary schools. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

INNES, L. 2011. *The South African school geography classroom: potential nursery for local tertiary GIS education* [Online]. [Accessed].

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

ISAACS, S. 2007. Survey of ICT and education in Africa: South African country report ICT in education in South Africa.

JEKEL, T., KOLLER, A. & STROBL, J. 2012. Austria: links between research institutions and secondary schools for Geoinformation Research and Practice. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York Springer.

JENSEN, T. P. 2012. Denmark: Early adoption and continued progress of GIS for Education. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

JOHANSSON, T. GIS in educator education – facilitating GIS applications in secondary school Geography. *In:*VIRRANTAUS, K. & TVEITE, H., eds. ScanGIS'2003: The 9th Scandinavian Research Conference on Geographical Information Science, 4-6 June 2003 2003 Espoo, Finland.

KERSKI, J. 2003. The implementation and effectiveness of Geographic Information Systems technology and methods in secondary education. *Journal of Geography,* 102, 128-137.

KERSKI, J. 2009. *The implementation and effectiveness of GIS in secondary education,* Saarbrücken, VDM Verlag Dr. Müller.

KERSKI, J., DEMIRCI, A. & MILSON, A. J. 2013. The Global Landscape of GIS in Secondary Education. *Journal of Geography,* 112, 232-247.

KIDMAN, G. & PALMER, G. 2006. GIS: The technology is there but the teaching is yet to catch up. *International Research in Geographical and Environmental Education,* 15, 289-296.

KIM, M., BEDNARZ, R. & LEE, S.-I. 2011. GIS education for educators in South Korea: Who participates and why? *Journal of the Korean Geographical Society,* 46, 382-395.

KIM, M. & LEE, S.-I. 2012. South Korea: GIS implementation profiles among secondary Geography educators. *In:*MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

LAM, C.-C., LAI, E. & WONG, J. 2009. Implementation of geographic information system (GIS) in secondary geography curriculum in Hong Kong: current situations and future directions. *International Research in Geographical and Environmental Education,* 18, 57-74.

LATEH, H. & MUNIANDY, V. 2011. Technology integrated teaching in Malaysian schools: GIS, a SWOT analysis. *World Journal on Educational Technology,* 3, 64-74.

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

LIU, Y. & TAN, G. C. I. 2012. Singapore: the information technology masterplan and the expansion of GIS for Geography education. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

MAKINSTER, J., TRAUTMANN, N. & BARNETT, M. 2014. Introduction. *Teaching science and investigating environmental issues with geospatial technology.* New York: Springer.

MILSON, A. J. & KERSKI, J. J. 2012. United States of America: rugged terrain and fertile ground for GIS in secondary schools. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

MOTA, M. 2012. Portugal: experimental science learning, webGIS, and the ConTIG project. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

MUῆIZ-SOLARI, O. & MOREIRA-RIVEROS, G. 2012. Chile: GIS and the reduction of the digital divide in the Pan-American world. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspective on teaching and learning with GIS in secondary schools.* New York: Springer.

OPPONG, J. R. & OFORI-AMOAH, B. 2012. Ghana: prospects for secondary school GIS Education in a developing country. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

RØD, J. K., ANDERSLAND, S. & KNUDSEN, A. F. 2012. Norway: national curriculum mandates and the promise of web-based GIS applications. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

RØD, J. K., LARSEN, W. & NILSEN, E. 2010. Learning geography with GIS: Integrating GIS into upper secondary school geography curricula. *Norwegian Journal of Geography,* 64, 21-35.

ROOSAARE, J. & LIIBER, Ü. 2013. GIS in school education in Estonia - looking for an holistic approach. *Journal of Research and Didactics in Geography,,* 1, 47-56.

SALAMANCA, L. A. R. & VEGA, N. A. D. 2012. Colombia: development of a prototype web-based GIS application for teaching Geography. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

SANCHEZ, E., GENEVOIS, S. & JOLIVEAU, T. 2012. France: dogmatic innovations, innovative educators, and parallel experimentations. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

SCHEEPERS, D. 2009. GIS in the geography curriculum. *PositionIT* [Online]. Available: eepublishers.co.za/images/upload/.../GIST-GIS-in-the-geography.pdf [Accessed 8 July 2011].

SOUTH AFRICA. DEPARTMENT OF BASIC EDUCATION 2004. White paper on e-education. *In:* EDUCATION (ed.). Pretoria: Government Printers.

SOUTH AFRICA. DEPARTMENT OF BASIC EDUCATION 2011. Curriculum and assessment policy statement (CAPS) Geography. *In:* EDUCATION (ed.). Pretoria: Government Printer.

SRIVASTAVA, S. K. 2013. Threshold concepts in geographical information systems: a step towards conceptual understanding. *Journal of Geography in Higher Education,* 37, 367-384.

STARK, H.-J. & TREUTHARDT, C. 2012. Switzerland: introducing geo-sensor technologies and cartographic concepts through the map your world project. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

STYLINSKI, C. D. & DOTY, C. 2014. The inquiring with GIS (iGIS) project: helping educators create and lead local GIS-based investigations. *In:* MAKINSTER, J., TRAUTMANN, N. & BARNETT, M. (eds.) *Teaching science and investigating environmental issues with geospatial technology.* London: Springer.

TIWARI, C. & TEWARI, V. 2012. India: localized introduction of GIS in elite urban private schools and prospects for diffusion. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

UNITED NATIONS 2012. Open access, virtual science libraries, geospatial analysis and other complementary information and communications technology and science, technology, engineering and mathematics assets to address development issues, with particular attention to education. *In:* COMMISSION ON SCIENCE AND TECHNOLOGY FOR DEVELOPMENT (ed.). Geneva: Economic and Social council.

WANG, Y.-H. & CHEN, C.-M. 2013. GIS education in Taiwanese senior high schools: A national survey among geography educators. *Journal of Geography,* 112, 75-84.

WHEELER, P., GORDON-BROWN, L., PETERSON, J. & WARD, M. 2010. Geographical information systems in Victorian secondary schools: current constraints and opportunities. *International Research in Geographical and Environmental Education,* 19, 155-170.

YAGHI, R. 2012. Lebanon: A personal journey from professional development to GIS implementation in an English language classroom. *In:* MILSON, A. J., DEMIRCI, A. & KERSKI, J. J. (eds.) *International perspectives on teaching and learning with GIS in secondary schools.* New York: Springer.

YAP, L. Y., TAN, G. C. I., ZHU, X. & WETTASINGHE, M. C. 2008. An assessment of the use of Geographical Information Systems (GIS) in teaching geography in Singapore schools. *Journal of Geography,* 107, 52-60.