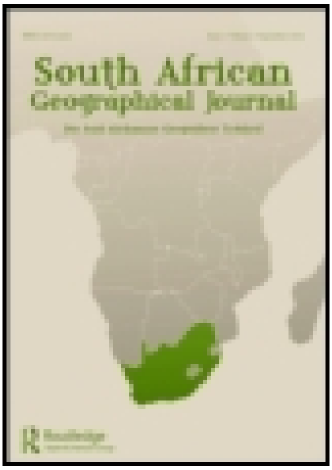

South African Geographical Journal
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rsag20

The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners

H.W. Britz[a] & P. Webb[b]

[a] Geosciences Department, Nelson Mandela Metropolitan University, PO Box 77000, NMMU, Port Elizabeth, 6031, South Africa

[b] School for Education Research and Engagement, Nelson Mandela Metropolitan University, PO Box 77000, NMMU, Port Elizabeth, 6031, South Africa

Published online: 13 Nov 2014.

To cite this article: H.W. Britz & P. Webb (2014): The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners, South African Geographical Journal, DOI: 10.1080/03736245.2014.977815

To link to this article: http://dx.doi.org/10.1080/03736245.2014.977815

South African Geographical Journal, 2014
http://dx.doi.org/10.1080/03736245.2014.977815

Routledge Taylor & Francis Group

The effect of an intervention using GIS-generated geo-spatial data on the promotion of spatial cognition and spatial perspective taking in grade 11 learners

H.W. Britz[a] and P. Webb[b]*

[a]*Geosciences Department, Nelson Mandela Metropolitan University, PO Box 77000, NMMU, Port Elizabeth, 6031, South Africa;* [b]*School for Education Research and Engagement, Nelson Mandela Metropolitan University, PO Box 77000, NMMU, Port Elizabeth, 6031, South Africa*

A question asked at the first national conference on the educational applications of geographical information systems (GIS) in Washington 1994, namely what learning does GIS allow that other ways do not and whether teaching GIS at school level is worth the time and effort required to implement it, remains largely unanswered. Literature searches suggest that little has been done to investigate the effectiveness of GIS in education since this question was raised. In investigating what learning using GIS allows that other ways do not, this study tested whether using GIS as a teaching and learning strategy enabled the promotion of learners spatial cognition and spatial perspective taking abilities better than traditional methods such as using atlases, rulers and calculators do. Four secondary Geography teachers in four Port Elizabeth schools volunteered to take part in the experimental aspects of this study. Empirical data on the development of spatial cognition and spatial perspective taking were generated via their grade 11 Geography learners. Experimental and comparison groups of learners wrote three different types of pre- and post-tests where the experimental groups worked on GIS software with geo-spatial data while the comparison groups used traditional methods. The empirical data generated by the learners revealed that GIS software and geo-spatial data do statistically significantly promote better spatial cognition and spatial perspective taking than traditional methods do.

Keywords: geographical information systems; geo-spatial data; GIS education; Geography; spatial cognition; spatial perspective taking

Introduction

Kerski (2003) highlights a question that was asked in 1994 by the National Conference on the Educational Applications of Geographic Information Systems (EdGIS), namely 'what learning does using Geographical Information Systems (GIS) allow that other ways do not'. Liu and Zhu (2008) believe that using GIS will enhance learners' spatial cognition and spatial perspective taking in geographic learning via learning activities such as collecting, storing, exploring and using geo-spatial data; making, using and interpreting maps; and investigating geographic issues. While Baker and Bednarz (2003) argue that some research results provide evidence that GIS can help learners to 'do science', they concede that there is a paucity of well-designed research studies on the effectiveness of GIS in education. Kerski (2003) maintains that no study proves GIS to be worth the time and effort of implementing it in schools. A literature search covering the decade from then to date indicated that little to nothing has changed in terms of the above statements since they were made.

*Corresponding author. Email: paul.webb@nmmu.ac.za

Kerski (2003) also remarked that it was, at that time, still unclear how and why GIS was being implemented in secondary school curricula, and pointed out that most of the literature on GIS implementation in education came from subjective and vested-interest accounts generated by for-profit organizations rather than by more disinterested researchers or more objective national or regional analyses. Again, literature searches from 2003 to date indicate little to nothing which makes one believe anything has changed.

Nevertheless, despite little empirical evidence, a number of claims have been made as to the benefits of using GIS in school Geography, one being Liu and Zhu's (2008) claim that it promotes the development of spatial cognition and spatial perspective taking. This claim, coupled with Kerski's (2003) and Baker and Bednarz's (2003) observations above, underpin this research study which attempts to measure any effect that using GIS software and geo-spatial data might have on promoting spatial cognition and spatial perspective taking in grade 11 learners. In doing so it should contribute towards answering the question of whether using GIS can offer Geography learners something that traditional methods when teaching Geography do not.

Background

Geography education is based on exploring real-world issues (Kerski, 2003), and GIS has the potential to incorporate issues-based and inquiry-based education, as well as to increase the relevancy and utility of Geography (Wanner & Kerski, 2003). As GIS is designed to collect, store, manage, retrieve, manipulate, analyse and visualize geo-spatial data, Chang (2010) argues that it makes teaching Geography easier. In turn, Wanner and Kerski (2003) see it as a promising means for implementing educational reform, which would include not only using different teaching methods (such as the use of GIS), but also the promotion of abilities that have not been explicitly concentrated on before (such as the development of spatial cognition and spatial perspective taking).

However, the learning potential of using GIS to promote spatial cognition and spatial perspective taking, both of which are important cognitive processes in learning higher level Geography in general and map work in particular (Breetzke, Eksteen, & Pretorius, 2011), remains debatable. As such, this study was designed to investigate these possibilities via a GIS-based intervention in a small sample of South African schools that have the hardware and software to be able to teach Geography using GIS software and geo-spatial data at secondary school level. Issues around spatial cognition and spatial perspective taking are dealt with in more detail below.

Spatial cognition

Cognition is about knowledge, its acquisition, storage, retrieval, manipulation and, in humans, the cognitive structures and processes that are part of the mind (Smelser & Baltes, 2001). Spatial cognition is concerned with the study of knowledge and beliefs about spatial properties of objects and events in the world (Smelser & Baltes, 2001). Spatial properties include location, size, distance, direction, separation and connection, shape, pattern and movement. Spatial cognition and spatial thinking are a collection of cognitive skills that enable learners to do spatial reasoning based on their conception of space and place (Liu, Bui, Chang, & Lossman, 2010). These authors argue that spatial thinking is the cornerstone of GIS technology and, as such, is an essential tool for supporting the development of spatial thinking skills.

Bloom (1956) identified cognitive learning, affective learning and psychomotor learning as the three domains or classes of learning. While all these classes are deemed important in terms of any learning, it appears that the specific types of learning required in Geography prioritize the cognitive class. This study made use of specifically designed cognitive pre- and post-tests based on Bloom's (1956) taxonomy of learning behaviours (which can be thought of as the goals of the learning processes) to evaluate spatial cognition in participants. These tests are based on the six major categories of the cognitive class, namely knowledge, comprehension, application, analysis, synthesis and evaluation, as listed by Bloom (1956). Test items in these tests were formulated to assess these six categories.

Spatial perspective taking

Geographers look at the world from a spatial perspective; they seek to understand the changing spatial organization and material character of the Earth's surface. The ability to think spatially is central to a person being considered as geographically literate and a sound spatial perspective taking ability is important to understanding and utilizing technological advances in Geography and geographic education, such as GIS (Oldakowski, 2007). One of the critical advantages of spatial perspective is that it allows one to understand and focus on how phenomena are related to one another in particular places (Fitzgerald, 2012). Zietsman (2002) believes that GIS is the technology of choice when dealing with issues of spatial perspective taking.

Kozhevnikov and Hegarty (2001) developed a test of spatial perspective taking (spatial orientation and spatial visualization) that was modelled after the types of stimuli used in experimental studies of perspective taking. In their study participants were shown a two-dimensional array of objects or a schematic map of a town, and were asked to imagine that they were facing a particular direction within the array or map. They were then required to indicate the direction to a target object in the array from the imagined perspective. Kozhevnikov and Hegarty (2001) concluded from their results that this test is a true test of spatial perspective taking (orientation and visualization) ability. In this study Kozhevnikov and Hegarty's spatial perspective taking test was used to test spatial orientation and spatial visualization of the participants.

Another test of spatial ability, the Purdue Visualization of Rotations (ROT) test, shows a highly significant correlation between spatial ability and spatially oriented tasks in general (Bodner & Guay, 1997). The ROT test was used in the post-crossover stage of this study in an attempt to provide an added perspective of the validity and reliability of the Kozhevnikov and Hegarty spatial perspective taking test as used in the context of this study.

Research design and methodology

In order to test whether GIS promotes the development of spatial cognition and spatial perspective taking in terms of Geography learners, a quasi-experimental crossover design with pre- and post-intervention tests for experimental and comparison groups was used. Two different interventions using GIS software and geo-spatial data were designed by the researchers in collaboration with the participating teachers. The first intervention was based on map work which was based on familiar work encountered in the grade 11 curriculum, while the second intervention was based on GIS theory and practice which was new to the students as they were unfamiliar with the theoretical concepts and GIS software that were used. Quantitative data were generated from these pre- and post-tests which tested spatial cognition and spatial perspective taking abilities. As noted earlier, two well-known and validated spatial perspective taking tests, namely Kozhevnikov and Hegarty's spatial perspective taking test and the ROT test, as well as a custom-designed spatial cognition test based on Bloom's taxonomy, were used for pre- and post-testing. The spatial cognition test was validated by the participating teachers, in other words by 'expert' peer validation.

The study investigated possible relationships between two variables using pre- and post-tests. Participants were selected from four volunteer schools and were randomly assigned to experimental or comparison groups using a random number table. Later in the study the roles were reversed using a crossover design, which means that the experimental group became the comparison group and the comparison group became the experimental group for the second part of the study. The independent variable, the treatment or intervention, was the use of GIS software and geo-spatial data, while the dependent variable was the effect of the strategy on learners' spatial cognition and spatial perspective taking (Liu et al., 2010). The experimental group received the treatment (use of GIS) during the intervention while the comparison group was taught (pre-crossover map work, post-crossover GIS theory and practice) in a traditional manner using atlases, rulers, calculators, etc. Before the intervention both groups wrote a pre-test, after the intervention a post-test was written and the outcomes between the pre-and post-test were measured in order to evaluate if there were a statistically significant difference between the scores of the two groups (the same test was used for the pre-test and the post-test).

A crossover design enables individuals in both groups (experimental and comparison) to receive the treatment (in this case working on GIS software) with a washout period between the two interventions (Wang, Lorch, & Bakhai, 2012). The benefit of using a crossover design is that it can be used in quasi-experimental investigations to generate sufficient data for statistical analyses where the number of participants is restricted (Lynch, 2010). The crossover design used in this study (see Table 1) was chosen for two reasons: first, because of the relatively small sample sizes available (Lynch, 2010), and, second, in order to give all the participants, all of whom had no previous experience of working with GIS software at the beginning of the study, the opportunity to work with GIS software.

The crossover design allows comparisons between the two groups (experimental and comparison groups) starting with a pre-test to determine equivalence between the groups. Thereafter each group acts as the others comparison group (Lynch, 2010) (after the pre-test, the intervention and post-test the groups switch over and undergo the alternative, treatment or no treatment, thereby acting as comparison groups for one another). Lynch (2010) warns that in this type of design (crossover design) there needs to be a washout period before or after switching the groups. The washout period allows for the possibility for any short-term observed effects to be lost (Lynch, 2010).

In this study the washout period was built in to minimize possible contamination and to limit this factor as a disadvantage to the design. A too short washout period will allow learners to carry over detailed content-specific knowledge (Lynch, 2010). In this study the washout period was the June/July school holidays in the middle of the school year. This period of five weeks was felt by the teachers involved and the researcher to be an adequate washout period between the two treatments because, in their experience, learners appear to retain very little detailed content-specific knowledge after returning from their mid-year break.

Table 1. Pre- and post-test crossover design.

Pre-and post-test crossover design

	Group A (experimental)	Group B (comparison)
STAGE 1 (pre-crossover)	Pre-test 1 on map work	Pre-test 1 on map work
	Intervention using GIS	Standard use of atlases, rulers, calculators etc.
	Post-test 1 on map work	Post-test 1 on map work
Wash-out period	Group A (comparison)	Group B (experimental)
STAGE 2 (post-crossover)	Pre-test 2 on GIS theory and practice	Pre-test 2 on GIS theory and practice
	Teaching and learning from geography textbook	Intervention using GIS
	Post-test 2 on GIS theory and practice	Post-test 2 on GIS theory and practice

Note: In the case of Kozhevnikov and Hegarty's spatial perspective taking test and the Purdue Visualization of Rotations (ROT) test the pre- and post-tests referred to prior and after the washout period were in fact only one test which was taken by the learners after the initial intervention. In the case of the spatial cognition tests, there were separate pre- and post-tests as shown on the diagram as they covered different aspects of work, namely map work and GIS theory and practice.

Setting and sample

The schools that participated in this study were drawn from the Port Elizabeth Education district. The schools had already obtained the GIS software that was used in this study (ArcView 3.3). A list obtained from ESRI, the vendors who sell ArcView 3.3, indicated that seven schools had bought the before mentioned software, and this fact was validated by questionnaires from 53 schools in the Port Elizabeth Education district which indicated that only the listed schools had the GIS software. The seven schools that had ArcView 3.3 were invited to take part in the study and four schools volunteered to take part. The four teachers who volunteered to take part in this study all teach Geography to grade 10, 11 and 12 learners. In discussions with the four participating teachers it was decided that the grade 11 Geography learners would take part in the study, as they would benefit more from the study than the grade 10 learners and the grade 12 learners would not have the time to take part. The four schools that volunteered to take part in the study were a boys-only school ($n = 21$), a girls-only school ($n = 26$), a special-needs school (mixed gender) ($n = 11$, 7 boys and 4 girls) and a private school (mixed gender) ($n = 9$, 6 boys and 3 girls). Overall these schools provided an equitable gender spread. All learners who took part in the study turned 17 in 2012 (the year of data collection).

Interventions

Two interventions took place throughout the duration of this study. The first intervention took place during the pre-crossover period and the second intervention took place in the post-crossover period of this study. The first intervention used map work that was familiar to the learners and the second intervention used GIS theory and practice that was unfamiliar to the learners.

For each intervention the exact same lesson was given to the whole class. During both interventions the experimental and comparison groups used a similar worksheet based on, as discussed before, map work or GIS theory and practice. The experimental group received the treatment, i.e. the opportunity to use GIS software and geo-spatial data to complete the tasks, while the comparison group used traditional materials such as atlases, calculators and rulers to complete their tasks. The two groups worked separately, while the experimental group worked in a computer room the comparison group worked in the Geography classroom.

Testing process

In this study pre- and post-tests were written to assess spatial cognition and spatial perspective taking ability in grade 11 Geography learners. Because the questions used in the spatial cognition tests, which were designed by the researchers within the framework of Bloom's taxonomy, were based on the curriculum material used, namely map work in the pre-crossover stage and GIS theory and practice in the post-crossover stage (see Table 2), two different spatial cognition tests had to be devised for assessing spatial cognition. These tests were validated by the participating teachers (Table 2 provides example questions from the pre- and post-tests). Kozhevnikov and Hegarty's spatial perspective taking test, which is a well-used and validated test, was used for assessing spatial perspective taking. As the same test was used each time, the pre-crossover spatial perspective taking post-test could be used as the pre-test for the post-crossover period.

As noted earlier, Kozhevnikov and Hegarty's spatial perspective taking test is a well-known and validated test which consists of 12 questions in which testees are shown a two-dimensional array of objects on paper and are asked to imagine that they are facing a particular direction within the diagram (Figure 1 provides an example). They then have to indicate the direction to a target object on the diagram. The answers to these questions are given a mark of 0 if the learner gets it completely wrong, and a half ($\frac{1}{2}$) mark is given to answers that are within the correct general direction and a full mark if the angle is correct (as described by Kozhevnikov & Hegarty, 2001). The spatial perspective taking tests were administered differently to the spatial cognition tests in that they were repeated administrations of the same test, that is a pre-test a mid-test and a post-test, with the mid-test serving as both the post-test for the pre-crossover stage and the pre-test for the post-crossover stage. The first pre-test for spatial cognition (map work) and the pre-test for spatial perspective taking were written at the same time before the intervention. The mid-test for spatial perspective taking was written at the same time as the map work spatial cognition post-test after the intervention, in the pre-crossover stage. The post-crossover spatial cognition pre-test (GIS theory and practice) was written just prior to commencing the post-crossover period of the study, i.e. after the mid-year school break.

Another set of pre- and post-tests were written in the post-crossover stage of the study, namely the ROT tests. These tests were used to complement Kozhevnikov and Hegarty's spatial perspective taking tests. Both the ROT tests and Kozhevnikov and Hegarty's

Table 2. Example questions taken from spatial cognition pre- and post-tests.

Category tested	Map work pre- and post-test (pre- crossover)	GIS theory and practice pre- and post-test (post- crossover)
Knowledge	On map 2, label the Olifants and Limpopo River	Define metadata
Comprehension	By looking at the contour patterns in map 3, predict the direction in which the river flows	Explain in your own words how GPS data is represented in a GIS
Application	Use the contours in map 3 to draw a longitudinal profile of the river and mark the waterfall and dam	How can you make use of satellite imagery to calculate the size of a cyclone storm
Analysis	Compare the two cross-sections and contour maps in map 4. Which cross-section shows an upper course river valley?	Differentiate between raster and vector data in a GIS (you may use pictures)
Synthesis	Describe your journey from point A to point B using the topographic map	Discuss shortly the types of data you would bring into your GIS to assist you in tracking a cyclone
Evaluation	Evaluate the effectiveness of using a vertical profile to show the difference between fast and slow flowing rivers	Justify the use of raster data when analysing a cyclone

spatial perspective taking test show a highly significant correlation between spatial visualization and spatially oriented tasks (Bodner & Guay, 1997; Kozhevnikov & Hegarty, 2001), but they differ in the way in which they test these attributes. The instructions for the ROT test ask participants to study an example showing rotation, and then to picture in his/her mind what another object shown would look like when rotated in exactly the same manner (Figure 2 provides an example). The participant must then select an answer from among five positional drawings of the object (Bodner & Guay, 1997). To restrict analytical processing, a time limit of 10 minutes for the test is strictly enforced.

The initial pre-tests (all of them) were written in the beginning of the school year and the map work intervention took place during May, while the first spatial cognition post-test and the spatial perspective taking mid-test were written before the June/July school holidays. The school holidays served as a washout period and the experimental and comparison groups were crossed over after the school holiday. The post-crossover spatial cognition pre-test and the ROT pre-test were written early in the second semester and the GIS theory and practice intervention took place in October, while the post-tests were written close to the end of the school year after the second intervention.

Data analysis

The data generated by the experimental and control groups were treated statistically to provide descriptive and inferential statistics. The possibility that one class was inherently more able was catered for by the use of covariance techniques. Cohen's d statistics were calculated to determine whether statistically significant ($p \leq 0.05$) pair-wise differences were practically significant. A Cohen's d effect size (d) between 0.2 and 0.5 is considered to be of small practical significance, an effect size between 0.5 and 0.8 is considered as being moderately practically significant, while an effect size of 0.8 and greater is considered to be highly practically significant. To provide a measure of internal consistency for the tests, Cronbach's α was calculated for all the pre-tests, mid-tests and post-tests used in this study.

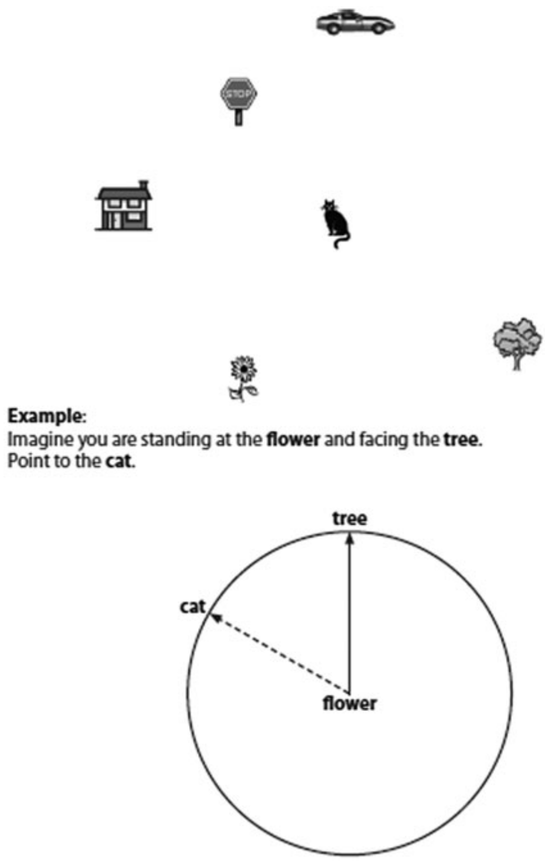

Figure 1. Example of a question from the Kozhevnikov and Hegarty (2001) spatial perspective taking/spatial orientation test.

Ethics

Permission to conduct the study was granted by the Nelson Mandela Metropolitan University and by the Eastern Cape Education Department. Prior to any data collection taking place, all principals and teachers who volunteered to participate in the study were informed of the nature and latitude of the research and were given the option to choose whether or not they would like to be part of the research process. Data from learners were generated by the teachers. The principals', teachers' and learners' right to anonymity was discussed, as well as their right to full disclosure regarding the research topic, results and recommendations.

Results

The analysis of the spatial cognition data revealed that there was only a statistically significant ($p \leq 0.05$) change between pre- and post-test means scores between the experimental and comparison groups for the category 'knowledge' ($d = 0.22$) in the pre-crossover stage of this study (see Table 3). The spatial cognition pre-crossover intervention was based on map work with which the learners were familiar. In contrast, a statistically significant change ($p \leq 0.05$) in pre- and post-test mean scores between the

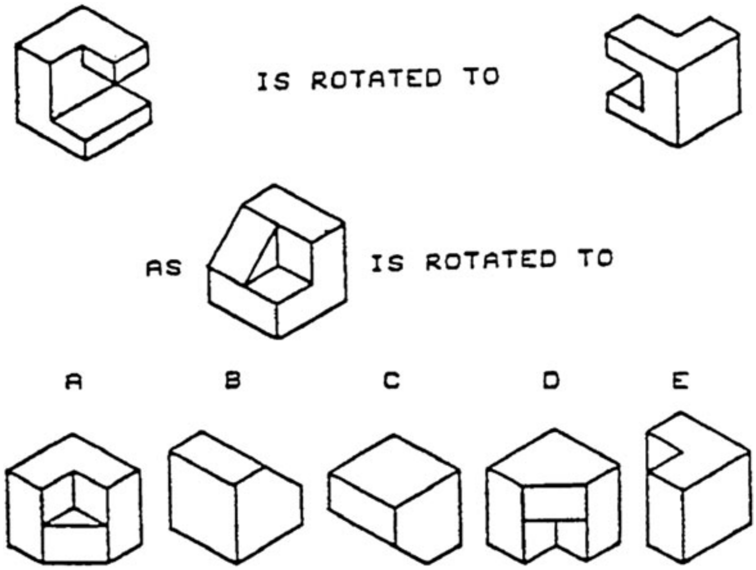

Figure 2. An example of a question from the Purdue Visualization of Rotations (ROT) test (Bodner & Guay, 1997).

experimental and comparison groups for the categories 'comprehension' ($d = 0.26$), 'application' ($d = 0.20$) and 'evaluation' ($d = 0.20$) was found in the post-crossover stage of the study when material unfamiliar to the learners was used during the intervention (see Table 4).

These data suggest that the use of GIS software and geo-spatial data can make a difference to spatial cognition abilities, particularly in novel situations, although for this study not of a particularly high practical significance. It appears that in the post-crossover period of the study, when the learners where introduced to a novel situation, they were better able to grasp the meaning of the material used in the intervention and were better able to demonstrate an understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions and stating main ideas; and solving problems by applying acquired knowledge, facts, techniques and rules in a different way and to present and defend opinions by making judgements about information. These results

Table 3. Comparison of the experimental and comparison groups' changes in mean score from pre- to post-test for spatial cognition (pre-crossover).

Category tested	Experimental group $\Delta\bar{x}$	Comparison group $\Delta\bar{x}$	Mean difference	p	d
Knowledge	0.23	−0.10	0.33	≤0.05	0.22 (small)
Comprehension	−0.28	−0.03	0.02	0.28	–
Application	0.79	0.73	0.06	0.40	–
Analysis	−0.10	−0.07	−0.03	0.46	–
Synthesis	0.21	0.48	−0.27	0.12	–
Evaluation	−0.21	0.23	−0.44	0.16	–

Note: A change in mean scores between pre- and post-test is denoted by $\Delta\bar{x}$. A positive mean difference score implies that the experimental group's change in mean score was greater than the change in mean score for the comparison group.

Table 4. Comparison of post-crossover change in mean score between pre-and post-tests of the experimental and comparison groups for spatial cognition.

Category tested	Experimental group $\Delta\bar{x}$	Comparison group $\Delta\bar{x}$	Mean difference	p	d
Knowledge	2.13	1.74	0.39	0.16	–
Comprehension	0.93	0.39	0.54	$\leq$0.05	0.26 (small)
Application	1.07	0.77	0.30	0.10	0.20 (small)
Analysis	0.70	0.61	0.09	0.39	–
Synthesis	0.80	0.84	−0.04	0.43	–
Evaluation	1.30	0.94	0.36	0.07	0.20 (small)

Note: A change in mean scores between pre- and post-test is denoted by $\Delta\bar{x}$. A positive mean difference score implies that the experimental group's change in mean score was greater than the change in mean score for the comparison group. The effect size for the changes in mean scores between the experimental and control groups were based on a classification of statistical significance at the 90% level of confidence ($p \leq 0.10$) for application and evaluation.

suggest that learners using GIS software and geo-spatial data improved on their spatial cognition, especially when confronted with new and unfamiliar teaching materials.

Statistically significant changes ($p \leq 0.05$) between pre- and post-test means scores between the experimental and comparison groups were reported for Kozhevnikov and Hegarty's spatial perspective taking test in both the pre- and post-crossover stages of this study (see Tables 5 and 6).

For both interventions (pre- and post-crossover stages of this study) the effect size was medium (see Tables 5 and 6). While the ROT tests, which only took place in the post-crossover stage of the study, corroborated these findings in terms of statistical significance, it only revealed a small ($d = 0.20$) practical significant difference between the experimental and comparison groups (see Table 7).

The calculated Cronbach's α values for Kozhevnikov and Hegarty's spatial perspective taking tests all returned acceptable α values, with α ranging between 0.7 and 0.9 (Tavakol & Dennick, 2011), but some of the values returned for the spatial cognition and ROT tests (α between 0.5 and 0.7 in both cases) were less than satisfactory. A possible explanation for the relative low α score calculated for the spatial cognition tests is the low number of items tested in each category (knowledge, comprehension, application, analysis, synthesis and evaluation), as was the case for the ROT test. Tavakol and Dennick (2011) explain that if there are too few test items then α will usually be low (<0.7). The ROT test used in this study had only seven test items because of time constraints during the study.

While there were gains in mean scores in both the experimental and comparison groups, which may be attributed to a variety of factors including maturation and

Table 5. Comparison of the experimental and comparison groups' change in mean score between pre-and post-tests for spatial perspective taking (pre-crossover).

Experimental group Pre–post-test $\Delta\bar{x}$	Comparison group Pre–post-test $\Delta\bar{x}$	Mean difference	p	d
4.34	2.98	1.36	0.02	0.56 (medium)

Note: A change in mean scores between pre- and post-test is denoted by $\Delta\bar{x}$. A positive mean difference score implies that the experimental group's change in mean score was greater than the change in mean score for the comparison group.

Table 6. Comparison of change in the experimental and comparison groups mean score between pre- and post-tests of for spatial perspective taking post-crossover.

Experimental group Pre – post-test ($\Delta\bar{x}$)	Comparison group Pre – post-test ($\Delta\bar{x}$)	Mean difference	*p*	*d*
2.70	1.12	1.58	0.01	0.69 (medium)

Note: A change in mean scores between pre- and post-test is denoted by $\Delta\bar{x}$. A positive mean difference score implies that the experimental group's change in mean score was greater than the change in mean score for the comparison group.

Table 7. Comparison of change of the experimental and comparison groups mean score between pre-and post-tests for ROT.

Experimental group Pre – post-test $\Delta\bar{x}$	Comparison group Pre – post-test $\Delta\bar{x}$	Mean difference	*p*	*d*
0.57	0.20	0.37	0.10	0.20 (small)

Note: A change in mean scores between pre- and post-test is denoted by $\Delta\bar{x}$. A positive mean difference score implies that the experimental group's change in mean score was greater than the change in mean score for the comparison group.

familiarity with the tests applied, and there were only small improvements in mean scores following the use of GIS, what is important in this study is that the differences in these changes in mean scores were statistically significant ($p \leq 0.05$) at a range of levels of practical significance. These data suggest that the intervention did have a positive effect on learners' spatial perspective taking abilities, which is important for understanding and utilizing technological advances in Geography and GIS education (Oldakowski, 2007).

Conclusion

The data suggest that in the post-crossover period of the study, when the experimental group of learners were introduced to a novel situation using GIS, they were better able to grasp the meaning of the material used in the intervention. Specifically they were better able to demonstrate an understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions and stating main ideas; and solving problems by applying acquired knowledge, facts, techniques and rules in a different way and to present and defend opinions by making judgements about information. The results overall suggest that using GIS software and geo-spatial data had a positive effect on the learners' spatial cognition abilities, especially when confronted with new and unfamiliar teaching materials. Furthermore, the use of GIS and geo-spatial data also improved their spatial perspective taking abilities, which is important for understanding and utilizing technological advances in Geography and GIS education (Oldakowski, 2007).

If the data generated by this study, which suggest that teaching with GIS software and geo-spatial data improves learners' spatial cognition and spatial perspective taking, are accepted, it is reasonable to say that, at least in terms of these abilities, implementing GIS software and geo-spatial data as a teaching strategy in schools is worthwhile and can offer something that other methods do not. However, this judgement must be balanced against the challenges and barriers that limit or prohibit the use of such methods in schools, particularly schools that are not equipped to do so in terms of hardware and software and teachers' ability and motivation. Nevertheless, the findings make a contribution to the debate on the use of GIS and the manipulation of geo-spatial data in that they support to some extent the untested claims made as to the positive effects of using GIS on spatial cognition.

References

Baker, T. R., & Bednarz, S. W. (2003). Lessons learned from reviewing research in GIS. *Journal of Geography*, *102*, 231–233.

Bloom, B. S. (1956). *Taxonomy of educational objectives, handbook I: The cognitive domain*. New York, NY: David McKay.

Bodner, G. M., & Guay, R. B. (1997). The Purdue visualization of rotations test. *The Chemical Educator*, *2*(4), 1–17.

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*, 148–157.

Chang, K.-T. (2010). *Introduction to geographical information systems* (5th ed.). New York, NY: McGraw-Hill.

Fitzgerald, E. (2012). Human geography. Retrieved from http://www.collegeboard.com/student/testing/ap/sub_humangeo.html

Kerski, J. J. (2003). The implementation and effectiveness of geographic information systems technology and methods in secondary education. *Journal of Geography*, *102*, 128–137.

Kozhevnikov, M., & Hegarty, M. (2001). A dissociation between object manipulation spatial ability and spatial orientation. *Memory and Cognition*, *29*, 745–756.

Liu, Y., Bui, E. N., Chang, C.-H., & Lossman, H. G. (2010). PBL-GIS in secondary geography education: Does it result in higher-order learning outcomes? *Journal of Geography*, *109*(4), 1–8.

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.

Lynch, C. (2010). *Doing your research project in sport*. Exeter: Learning Matters.

Oldakowski, R. K. (2007). Activities to develop a spatial perspective among students in introductory geography courses. *Journal of Geography*, *100*, 243–250.

Smelser, N. J., & Baltes, P. B. (2001). *International encyclopedia of the social & behavioral sciences*. Oxford: Pergamon Press.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55.

Wang, D., Lorch, U., & Bakhai, A. (2012). *Clinical trails a practical guide to design, analysis, and reporting*. London: Remedica.

Wanner, S., & Kerski, J. (2003). The effectiveness of GIS in high school education. Retrieved from http://proceedings.esri.com/library/userconf/proc99/proceed/papers/pap203/p203.htm

Zietsman, H. L. (2002). Geographic information science in South Africa. *South African Geographical Journal*, *84*, 30–37.