DEVELOPMENT AND EVALUATION OF A SELF-INSTRUCTION METHOD FOR ANALYSING SPATIAL INFORMATION

Lorraine Mary Innes

(BA, UNISA; HED, UNISA; BA Hons, Wits; MEd, Wits)

Thesis Presented for the Degree of

DOCTOR OF PHILOSOPHY

Science Faculty, Department of Environmental and Geographical Science

UNIVERSITY OF CAPE TOWN

June 2009

DEDICATION

To David who stood beside me
and Clare who held me up

ABSTRACT

The extent and consequences of problems related to analysis of spatial information at secondary school in South Africa, arising from historic inadequacies of human and material resources, are investigated. The post-apartheid education policy revision provides for improved spatial competence but a search for practical teaching guidelines in the outcomes-based education curriculum documents was unsuccessful. Theories of spatial cognition, cartographic communication and 'real world' comprehension are related to the development of spatial competence. The potential for geographic information systems (GIS) to enhance spatial concept development through visualisation of spatial data is identified. A postal opinion survey confirmed that a self-instruction programme for map reading (*MapTrix*, Innes, 2001) is effective. Using the test-intervention-test method, the importance of mathematics instruction for improving map analysis is recognised. Use of an opinion survey, conducted in an interactive workshop environment with a GIS-user focus group, guided the identification of foundation tasks associated with spatial analysis and an appropriate hierarchy for introducing the cumulative learning required to undertake those tasks. An appropriate instruction design model is identified and, focussing on the 1:50 000 topographic map of South Africa, learning materials are developed to address spatial learning needs using a GIS platform and PowerPoint to deliver the programme. Map reading is a pre-requisite skill for map analysis. To ensure their proficiency as map readers and to prepare participants to trial the prototype computer-assisted map analysis programme, MapTrix Geomatica, they were first introduced to the computer-instruction environment using the MapTrix Digital Game (a prototype of the digital conversion of *MapTrix*). The test-intervention-test method confirmed the effectiveness of the map reading game and was used again for the evaluation of MapTrix Geomatica. The trials were conducted with four different groups of participants in both holiday-volunteer and school-based environments. Results indicate that the programme succeeded in improving map analysis scores, that self-instruction is effective with management and guidance by a trained teacher and that GIS provides an effective delivery mechanism for a spatial analysis learning programme. Improvements to the prototype are recommended.

PREAMBLE

The central argument of the research is that the self-instruction method can be used to improve map analysis skills. These skills are distinct from pre-requisite map reading skills for which a paper-based self-instruction programme was published some time ago (*MapTrix*, Innes 2000). The main goal of the research is the development of a prototype learning programme to teach the more advanced map analysis skills. The ten chapters of the thesis do not represent a chronological research process. For clarification they have been grouped in Figure P.1 into four phases – the problem identification phase, design phase, development phase and evaluation phase. It is acknowledged that the report describes a research and development project, undertaken in the real world of learners and schools and not in a highly controlled experimental situation.

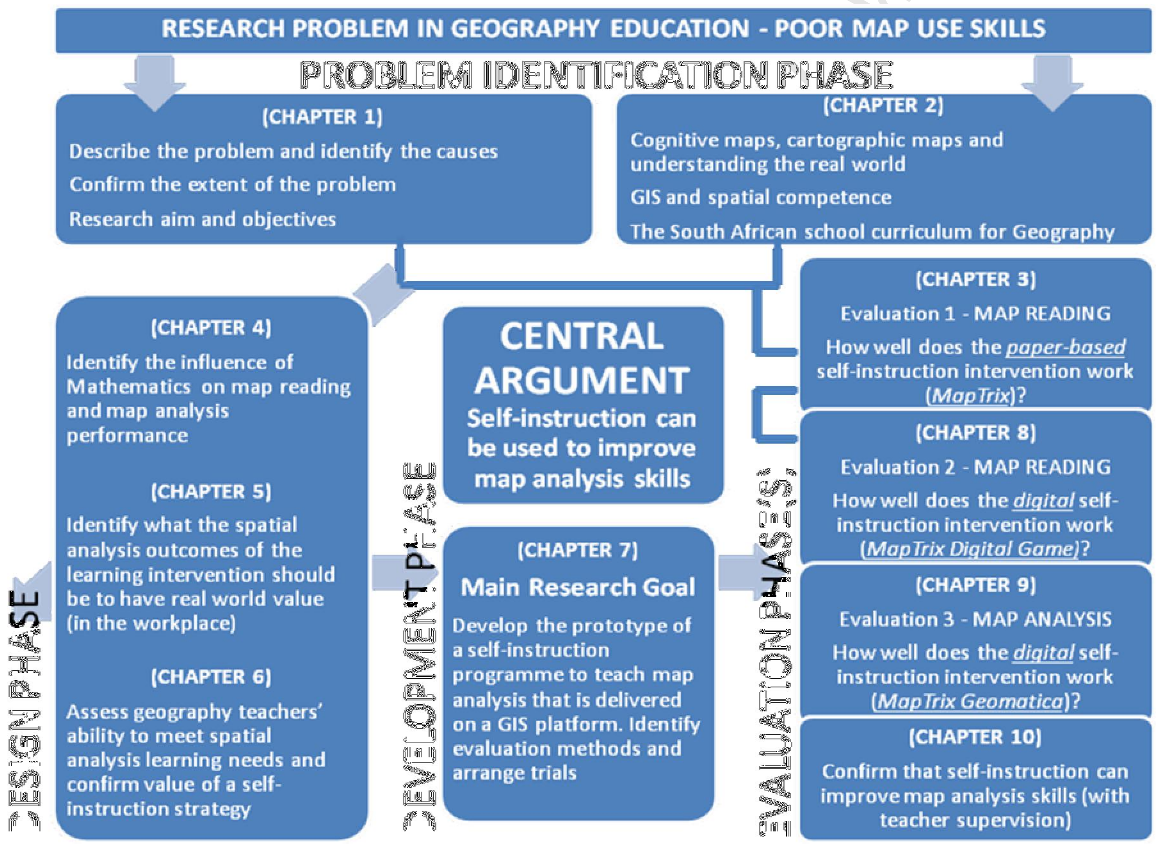


Figure P.1 Flow diagram illustrating four phases of the research process

That there is a long standing problem with map use in South Africa and elsewhere is established from a survey of international and local investigations on the subject covered at the start of Chapter One. The importance of spatial information is stressed and stakeholders in improving access to such information are identified. The history of geography teaching in South Africa is briefly reviewed and then the National Qualifications Framework (NQF), introduced after 1994, is described. Poor map use performance in the school leaving geography examinations from 2000 to 2007 is highlighted. In Chapter Two theories related to cognitive maps, cartographic map comprehension and real world perception and how they aid in the development of the ability to use maps and other spatial information products (spatial competence) are reviewed. The role of geographic information systems (GIS) in enhancing spatial competence is discussed. Whether or not relevant skills might be impacted, in a practical way, by South Africa's new National Curriculum based on the NQF is then assessed.

Chapter Three forms the first part of the evaluation phase. It was important to assess the use of the paper-based self-instruction method to teach map reading so that the self-instruction method could be incorporated with confidence in the design phase of the proposed programme for improving map analysis skills. The link between this Chapter and Chapter Eight is *MapTrix*; the one deals with the paper-based version of the map reading learning game, the other deals with the digital version.

Informed by the findings of Chapters One, Two and Three, Chapters Four to Six describe further factors that are considered in the design phase of the project. The influence on map analysis skills of the school subjects Mathematics, Science and Geography is assessed in Chapter Four. In order to identify which map analysis skills are most important, their use in the work-place is investigated at the start of Chapter Five, following which spatial competence is defined in detail and specific learning outcomes are identified. The ability of South African geography teachers to meet spatial learning needs, an issue already raised in Chapters Three and Four, is discussed further in Chapter Six, confirming the value of providing self-instruction learning and teaching support materials (LTSM) to meet both teachers' training needs as well as the needs of their learners.

Chapter Seven is a report on product development. In it are described the writing of the learning programme text (lessons and exercises) and identification of resources and their organisation into the various map analysis learning units for the programme, their conversion to the digital environment using Microsoft PowerPoint™ and how these were linked together using GIS software. The chapter includes a description of the test-intervention-test evaluation method used in the trials of the MapTrix Geomatica prototype. The development of a digital version of *MapTrix*, used to prepare trial participants, is briefly described concluding the chapter covering the development phase.

The balance of the evaluation phase is reported in the last three chapters. Chapter Eight opens with an overview of the data collection instruments and trial population groups and then describes the evaluation of the MapTrix Digital Game for map reading, which was used in a pre-intervention strategy to prepare learners for the trials of the GIS-based map analysis programme. In Chapter Nine the results of the evaluation of MapTrix Geomatica are reported, focussing on the impact of the programme on learners' map analysis performance. In Chapter Ten the research findings are discussed revealing that MapTrix Geomatica can have a positive impact on map analysis performance but, while self-instruction is effective, it requires a suitably trained teacher for guidance and management of the learning environment. GIS successfully delivered the spatial information resources required for the map analysis learning programme and contributed towards the participants' positive attitude to the programme. Recommendations are made for improvements to and further development of the prototype and its wider potential advantages for teacher training are outlined.

ACKNOWLEDGEMENTS

A number of organisations, their affiliates and many kind individuals contributed towards this investigation and all are gratefully acknowledged, especially the teachers and education administrators nationally who responded to the *MapTrix* Questionnaire Survey. The following are mentioned with special thanks.

Chief Directorate of Surveys and Mapping:

- Dr Derek Clarke and Thomas Krieg for securing state funding for the publication of *MapTrix* and making the resources available to conduct the *MapTrix* Questionnaire Survey
- Mariana French, Peter Bowerman, Wally Kuhnert and their technical staff for expertise and co-operation in the preparation of the map extracts for both the paper and digital versions of *MapTrix*
- Steven Jansen for assistance with data entry and analysis of both school address data for the survey and the geography practical matriculation examination data
- Linda Fedder for library research assistance
- The MapAware team for ongoing support and encouragement.

Eltanin Aeronautical Academy (formerly Quality Training Technologies)

- Dr Marna Cellier-Hartslief for introducing *MapTrix* to the organisation
- Sias Dreyer for seeing the potential of a digital conversion and not losing faith
- Mike Muuren for the initial planning and monitoring of the conversion to the MapTrix Digital Game
- Karel Calitz for completing the beta version of the game.

Naperian GIS Technologies

- Clyde Mallinson who proposed the collaboration to build MapTrix Geomatica and supported the process with staff and resources
- Caryll Tyson and Debbie Stott for populating the database and converting the lesson and exercise text into an interactive presentation
- Banele Dube for provided technical back-up, without which the first trials could not have progressed so smoothly.

University of Cape Town

- Professor Peter Holmes for initially supervising the research (before leaving UCT)
- For providing the venue for the first trials of MapTrix Geomatica
- Lynne McEwan for volunteering assistance as an expert geography teacher and research assistant
- Shirley Butcher for welcoming the author into her GIS Honours course
- Professor Mike Meadows for taking over supervision of the research with occasional assistance from Dr Kevin Winter.

Western Cape Education Department, for permission granted

- To involve teachers in collaborative LTSM development during MapAware teacher upgrading workshops; particular thanks go to those teachers who contributed with such enthusiasm
- To conduct trials of the MapTrix Digital Game (and MapTrix Geomatica) on state premises during school hours

In light of ethical principles and the identity restriction placed on the state school that participated in the trials it has been considered prudent not to name any of the schools involved in the trials. Nevertheless the assistance of all learners (especially holiday volunteers), teachers, and other support staff at all the schools is very gratefully acknowledged.

Thanks go to members of CaGIS and the Commission on Children and Cartography who participated in the definition of spatial competence and identification of a hierarchy of map analysis skills. The completion of the research and final preparation of the thesis rested ultimately on the help received from Dr Clare van der Willigan. The statistics training she provided to the author and her assistance with data analysis was invaluable. Her willingness to read chapters and respond instantly with guidance and comments was the encouragement required to keep going, especially towards the end of the project.

TABLE OF CONTENTS

CHAPTER 2
ENHANCING SPATIAL COMPETENCE

CHAPTER 3
EVALUATION OF A SELF-INSTRUCTION METHOD FOR TOPOGRAPHIC MAP READING

CHAPTER 6
GEOGRAPHY TEACHERS' ABILITY TO MEET SPATIAL LEARNING NEEDS

CHAPTER 7
INTERVENTION INSTRUMENTS, EVALUATION METHOD AND SETTING UP THE TRIALS

LIST OF APPENDICES

PLEASE NOTE: All figure and table references in the appendices are prefixed with 'A' to distinguish them from figures and tables in the main text of the thesis.

CHAPTER 8

CHAPTER 9

LIST OF FIGURES

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 10

LIST OF TABLES

CHAPTER 1

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

CHAPTER 7

APPENDICES 7.3, 7.4 and 7.5

CHAPTER 8

APPENDIX 8.8

CHAPTER 9

ABBREVIATIONS and/or EXPLANATION OF TERMS

ABET	Adult Basic Education and Training: addressing the needs of those deprived of education in childhood and/or basic skills training after school
AGSSS	Advancing Geospatial Skills in Science and Social Science
ANOVA	Analysis of variance
AS	Assessment Standard (by which Learning Outcomes in South Africa's outcomes based education system are measured)
AUME	Advisory Unit for Microtechnology in Education
CaGis	Contraction of Cape GIS user group: based in the Western Cape Province of South Africa, now incorporated into the Western Cape Branch of GISSA
CASE	Cognitive Acceleration in Science Education
CAT	Computer assisted training
CBT	Computer based training
CCC	Commission for Cartography and Children in the International Cartographic Association (ICA)
CDSM	Chief Directorate of Surveys and Mapping, the national mapping organisation of South Africa
CGE	Commission on Geography Education in the International Geographical Union (IGU)
CGIS-NUR	Centre for GIS and Remote Sensing of the National University of Rwanda
CHE	Committee of Heads of Education
CHED	Committee of Heads of Education Departments
CSC	Core Syllabus Committees
Curriculum 2005 (also C2005)	Unified education curriculum for all South African learners, which replaced the outdated, racially divisive education system of the previous government
DEM (see also DTM)	Digital elevation model
DET	Department of Education and Training (responsible for 'Black' education under apartheid legislation in South Africa)
DLA	Department of Land Affairs
DoE	Department of Education (post-1994 national body responsible for education of all learners in South Africa)
DoL	Department of Labour
DTM (see also DEM)	Digital terrain model
EMIS	Education Management Information System
ESKOM	Contraction of the Afrikaans language translation of the electricity supply commission of South Africa
ESRI	Environmental Systems Research Institute
FET	Further Education and Training
FETC	Further Education and Training Certificate (offered after 12 years of schooling)
FOSS4G	Free and Open Source Software for GIS
GA	Geographical Association
GDEST	Global Dialogues for Emerging Science and Technology
GET	General Education and Training
GETC	General Education and Training Certificate (offered after 9 years of schooling)
GIMS	Geographic Information Management Systems (South African GIS company)
GIS	Geographic Information System
GISSA	Geo-information Society of South Africa
GPS	Global Positioning System
Group Codes	Used to identify five different groups of trial participants
Group PB	Group of participants from a private boys school that trialed only MapTrix Geomatica
Group PI	Group of participants from a private international school that trialed only MapTrix Geomatica
Group SS	Group of participants from a single state schools that trialed both the MapTrix Digital Game and MapTrix Geomatica
Group SV	Group of participants from various state schools that trialed both the MapTrix Digital Game and MapTrix Geomatica
Group SX	Group of participants from the state school that trialed only the MapTrix Digital Game
GST	Geospatial technologies
HET	Higher Education and Training
HSRC	Human Sciences Research Council

ICA	International Cartographic Association
ICT	Information communication technology
IDRISI	A raster GIS developed by the Graduate School of Geography at Clark University and named after a cartographer born in 1099 in Morocco
IE	Instrumental Enrichment (Feuerstein, 1980)
IGU	International Geographical Union
ISASA	Independent Schools Association of South Africa
IT	Information Technology
JMB	Joint Matriculation Board
LO	Learning Outcome (measured by Assessment Standards in South Africa's outcomes based education system)
LPG	Learning Programme Guidelines
LTSM	Learning and Teaching Support Material
MapAware	National map awareness and map literacy campaign of the NMO (1997-2002)
MapPack	Package of maps made available to schools at no cost by the NMO
MapTrix (also *MapTrix Kit)*	A self-instruction programme for learning to read the South African 1:50 000 topographic map (Innes, 2000)
MapTrix Video	A training video used to introduce *MapTrix* (CDSM, 2000)
Matriculation (also Matric)	Traditional name of the South African school leaving qualification offered for examination after 12 years of schooling. Originally it referred to matriculation exemption (from university entrance examinations)
MEC	Member of the Executive Council (of a South African province)
n	number of observations
NCET	National Council for Education Technology
NCGIA	National Centre for Geographic Information and Analysis
NCS	National Curriculum Statement (Grades 10 to 12)
NMO	National Mapping Organisation
NQF	National Qualifications Framework
NRC	National Research Council (of the National Academies, USA)
ns (see also s)	not statistically significant
NSB	National Standards Body
NSC	National Senior Certificate
NSDI	National Spatial Data Infrastructure
OBE	Outcomes Based Education
OS	Ordnance Survey
p	probability
RNCS	Revised National Curriculum Statement (Grades R to 9)
r_s	Spearman's rank correlation
s (see also ns)	statistically significant
SA	South Africa
SABS	South African Bureau of Standards
SAG	Subject Assessment Guidelines
SANDF	South African National Defence Force
SAPS	South African Police Service
SAQA	South African Qualifications Authority
SD	standard deviation
SE	standard error
SG	Surveyor(s)-General: responsible for all cadastral information. The abbreviation is usually used with reference to their offices of which there are 4 in South Africa
SGB	Standards Generation Body
SITA	State Information Technology Agency
SSAG	Society of South African Geographers
Student's t test	Statistical hypothesis test for significance between two normally distributed means
TBVC States	Former South African homeland states of Transkei, Bophuthatswana, Venda and Ciskei
UCT	University of Cape Town
UNISA	Contraction of University of South Africa
USGS	United States Geological Services
UWC	University of the Western Cape
WCED	Western Cape Education Department
WITS	Contraction of University of the Witwatersrand, Johannesburg

CHAPTER 1

TEACHING MAP SKILLS IN SOUTH AFRICA

> *"Were all the maps in the world destroyed and vanished under the direction of some malevolent hand, each (one) would be blind again, each city made a stranger to the next, each landmark become a meaningless signpost pointing to nothing."*
>
> *Beryl Markham (aviatrix) quoted in Walford, 1999: 28*

1.1 INTRODUCTION

Maps, whether delivered via pixel or paper, are central to decision making in all matters related to land. In the sustainable development arena there are very few decisions of importance that have no spatial component; it is here that maps have a central role to play. However, the valuable spatial information they contain is inaccessible to those who cannot read, analyse and interpret maps. While professional decision makers such as government planners, land surveyors or engineers may be proficient users of spatial information, those communities upon whom their decisions have the most impact are often not able to participate in the decision making process because of their inability to access spatial information. In developed countries, map skills are considered life skills; the basics are taught to learners at primary school and the skill of using maps proficiently (or spatial competence) is further developed at secondary school.

The spatial competence of a significant percentage of school leavers in South Africa, even those who have taken Geography, is poorly developed. Apart from participating in decision making related to the many reconstruction and development projects initiated by the post-apartheid government, the growth of the spatial information industry demands a citizenry that is both aware of and competent to use spatial information. Global positioning systems (GPS) and geographic information systems (GIS) are increasingly impacting on every aspect of service delivery. With improved standards of living, communities have become more mobile, more informed, more able to access technology and thus more reliant on spatial information. The challenge is to meet that need to know WHERE.

1.1.1 One step forward, two steps back

The author's geography teaching, tutoring and lecturing experience at various locations and institutions created an awareness of serious problems with maps experienced by a significant percentage of learners at secondary school, teacher training and university levels in South Africa. The outcome of one attempt to address their spatial learning problems was the publication of *MapTrix: a self-instruction programme for learning to read the 1:50 000 topographic map of South Africa* (Innes, 2000) informally referred to as *MapTrix* or the MapTrix Kit. The development and initial evaluation of this paper-based package of learning materials was the subject of a Master of Education dissertation (Innes, 1998). The initial publication was sponsored by the South African national mapping organisation (NMO) and has been approved for distribution to schools by all nine Provincial Education Departments. Although contracts have been prepared for the MapTrix Kit to go into its fourth impression, attesting to the effectiveness of the self-instruction method for improving map skills, it is limited to the teaching of *map reading* only.

Before producing self-instruction materials a task analysis must be conducted, firstly to identify each learning unit that is required and secondly to structure the programme so that the units are arranged to make incremental learning possible (Gagné and Briggs, 1974). Task analysis, based on the practical skills component of the school geography syllabi that was in use at the time when the *MapTrix* investigation started, revealed three distinct levels in the map skills hierarchy – reading, analysis and interpretation. Having placed a self-instruction map reading programme in the hands of learners, the next skill level to be addressed is *map analysis*.

Taking a bold step forward, GIS was recognised as a valuable tool for teaching map skills using the associated visualisation and analysis tools. Before incorporating this technology into a school-level learning programme for map analysis, it was first necessary to take one step back and review the current state of spatial skills in South Africa and then to take another step back to find a starting point at which the technology could be applied to improve those skills. Because of the paucity of map use teaching skills in the country, self-instruction was investigated as a means to address poor map analysis skills at secondary school level.

To begin the process, Chapter One briefly reports on major international and local investigations into problems associated with map use. The importance of spatial information in various fields is stressed and the stakeholders in improving access to such information are identified. Because of its impact on map use competence, the history of geography teaching in South Africa is briefly reviewed and then the National Qualifications Framework (NQF), introduced after the fall of the Nationalist Party government in 1994, is described. Results of the school leaving geography examination for the period 2000 to 2007 still highlight poor map use performance. Lastly, the aim, objectives and scope of the project, the questions raised and the research methods used to address them are outlined.

1.1.2 International research into children's map use problems

The problem of poor performance in map use activities is not confined to South Africa. Just north of our border, Davies (1983) identified problems in the use of topographic survey maps among secondary school pupils in Zimbabwe. She attempted to discern a hierarchy of difficulty so as to plan appropriate teaching strategies. In the 1980's, primary and secondary pupils' difficulties with both survey and atlas maps were investigated in many countries: England (Boardman, 1983; Sandford, 1989), Netherlands (van der Schee, 1989), Nigeria (Okpala, 1989) and Denmark (Raadam, 1989) to mention a few. The specific difficulties associated with teaching primary school learners the three-dimensional representation of the landscape on maps was summarised by Burton (1989a).

The 1990's saw an upsurge of research in this area stemming rather from cartography than from a geography education perspective. Concern about children's abilities and map use is summed up in the following quotation from the foreword to the proceedings of a seminar on Cognitive Maps, Children and Education in Cartography: 'To teach the next generation how to use maps is the most important challenge of cartography and we realise that not much is known yet and (much) should still be researched' (Anderson *et al.*, 1996: ii). The seminar, held in Japan, was the first one of the Working Group on Cartography and Children, which came into existence at the General Assembly of the International Cartographic Association (ICA) in Barcelona in 1995. Papers dealt with topics such as children's cognitive issues (Livieratos, 1996 and Pravda, 1996), children's attitudes to maps (Anderson, 1996; Konečný and Švancara, 1996) and their map representations (Wiegand, 1996). Teaching materials for cartographic education were reviewed (Meissner, 1996) and using games was outlined by Feldmann (1996). The ICA Commission on Cartography and Children (CCC) aims, internationally, to:

- promote the use and enjoyment of maps by children and young people;
- increase understanding of children and young people's engagement with maps;
- raise the standard of maps and atlases produced for children and young people.

(Anderson, 2003)

Among geography education researchers there appeared to be limited interest in how teachers were dealing with map use problems during the 1990's. Gerber and Lidstone (1996) include only one chapter on map use (Kwan, 1996) out of fourteen in *Developments and Directions in Geographical Education*. At the International Geographical Union (IGU) Conference held in Durban, South Africa in 2002, of the 28 papers presented in the Commission on Geography Education (CGE) sessions, only two dealt with map use problems (Innes, 2002; Engel, 2002). Interest among cartographers continued and at the International Cartographic Association Conference held in Durban the following year, eight papers were presented in the two Cartography and Children sessions. Anderson (2003) presented an overview of research this field and posed a series of research questions to guide future research in this area. Many of the papers linked geography themes with cartography teaching. Garra *et al.* (2003) looked at teaching about risks and natural disasters and Passini *et al.* (2003) dealt with teaching local Geography using maps. Herzig and Jarausch (2003) discussed the development of cartographic and spatial comprehension related to a children's map drawing competition. Michaelidou *et al.* (2003) compared the differences between the spatial knowledge acquisition about their home country (Greece) of children of different cultures. A significant focus of the balance of the papers was on using digital maps and other digital spatial data in the classroom (Wiegand, 2003; Owen, 2003; Papadopoulos *et al.* 2003). Included in a session on Education and Training in Cartography, a paper was presented defining functional map literacy (Clarke, 2003). The use of low cost paper globe-maps to aid cartographic education at school level was defended in a poster by Anderson and Innes (2003).

The move towards the inclusion of information technology (IT) in geography teaching was evidenced at the Joint ICA Commissions Seminar which formed part of the 2005 ICA Conference. Of the 16 papers related to teaching map skills, nine referred to digital maps, mostly used at high school (Petersen, 2005; Williams, 2005; Zentai and Dombóvári, 2005; Caquard *et al.*, 2005; Hanewinkel and Tzschaschel, 2005; Anderson *et al.*, 2005; Wiegand, 2005; Cartwright, 2005). In comparison, seven papers discussed aspects of teaching map skills using conventional atlases or paper-based maps, again mostly at high school (Shingareva and Krasnopevtseva, 2005; Mihályi, 2005; Fairburn, 2005; Handoyo, 2005) while Livni and Bar's (2005) paper dealt with teaching map related concepts in the earth sciences to disabled learners of varying ages. Two papers (Galle and Reyes, 2005; Kwan and Chan, 2005) reported work with primary school learners using paper maps while Owen's (2005) paper discussed the monitoring of discourse during computer based mapping activity by learners in primary grades.

Of the 87 papers carried in the 2006 *Proceedings of the IGU's Commission on Geographical Education Symposium* in Brisbane, 14 dealt with map teaching issues. While Wiegand lamented that, in '... the UK and elsewhere, discourse in geography education has steadily, and over a lengthy period, drifted away from maps as a key pedagogical issue' (Wiegand, 2005: 149) it appears that this trend has been counteracted by the rapid and unprecedented growth of the IT industry, the internet and its opportunities for information and communication technology (ICT), GIS and, more recently, the availability of web-based GIS. This growth has been referred to as a communicative revolution: '...a new way of managing information (which) appears as a very powerful means for social communication, whose most attractive feature is interactivity' (Casti, 2005: 191). These developments seem to have revived an interest in how young people interact with maps and other spatial information, initially using IT as an introductory step towards digital maps and mapping. Ten papers on using GIS at secondary school level were presented at the IGU conference (Andersland, 2006; Herzig, 2006; Ida, 2006; Kankaanrinta *et al*., 2006; Lawrence, 2006; Maguire, 2006; Robertson and Fluck, 2006; Van der Schee, 2006; West, 2006; Zwartjes, 2006), each reporting varying degrees of success. Morgan and Freeman (2006) incorporated maps and mapping in both paper-based and digital formats into their discussion of action research agendas based on children's geographies for 11-16 year olds. Ekiss and Trapido-Lurie (2006) discussed the value of providing outline maps (both paper based and digitally downloadable) to improve teaching of place representation at both primary and high schools and, addressing the learning needs of a similar group, Wiegand's (2006a) paper offered guidelines for improving the way learners are taught about maps so that their own map generation in both formats can be improved across all grades.

In reviewing the 87 papers presented at the abovementioned symposium it became increasingly difficult to separate papers dealing specifically with map learning issues from those dealing with inquiry or problem based investigations (e.g. Chen and Li, 2006) and theoretical issues such as geographic reasoning (Benimmas, 2006) and geographic wisdom (Morgan, 2006). This is in no way a criticism; the integration of spatial competence into all aspects of geography teaching is to be applauded. The focus of geography teaching on sustainability issues (e.g. Ferreira, 2006; Lee, 2006) and on understanding multiculturalism (e.g. Bednarz *et al*., 2006; Johnston-Anumonwo, 2006) or both (Boehn and Henry, 2006; Min and Dongying, 2006) also entails the use of maps at a variety of scales. Nevertheless, in the search for guidelines for designing the step by step hierarchy of spatial analysis skills required for a self-instruction programme, the work of these researchers proves to be of great interest but of little direct assistance.

1.1.3 National research into map use problems at school level

South African children have traditionally started school anywhere between four and seven years of age and then followed a seven year primary/five year secondary school programme. Although the problems associated with the poor map skills of South African secondary school learners have been a matter of concern for some time, only a few research reports have appeared over the last three decades. Burton (1986) discussed the problems associated with poor performance in relief mapwork, later claiming that these problems had been reported by examiners for many years in South Africa (Burton, 1989b). Ndlwana (1991) analysed the problems experienced by secondary school pupils in the Transkei region of South Africa when working with both topographic maps and aerial photographs. In an attempt to solve map use problems in secondary school, Smit (1994) made valuable suggestions for teaching map use, including proposing an elementary model for teaching topographic map study based on symbol colour differentiation. Innes (1998) highlighted self-instruction as a method for improving topographic map reading. At primary school level, Potgieter and Olën (1993) reported on a map reading skills project and, while not confining her study to map use alone, Wilmot (1998) investigated graphicacy as a form of communication at the primary level. Vlok's work (1992) on school desk atlases offers guidelines for increasing and improving map use in primary and high school classrooms.

Poor map use performance at high school level translates into problems for geography lecturers at tertiary education institutions. It is at this level that the research has been a little more prolific. Magi (1981) drew attention to the poor perception of school Geography held by Black university students. Both Davies (1988) and Cowie (1994) reflected on the relationship between the standard of Geography at high school and university. Sekete (1995) discussed topographic map comprehension problems experienced by first year teacher training college students. Liebenberg (1998) outlined the problems of teaching map use at university level to students who had very different levels of apartheid-style school education. In trying to bridge the gap between the performance displayed by entry-level candidates and tertiary level expectations, a co-operative learning method to teach mapwork to tertiary level geography students has been proposed (Tshibalo and Schulze, 2000). Tshibalo (2003) then went on to show that the method also worked well with Grade 11 and 12 learners.

The albeit limited research in South Africa reveals that learning to use maps poses a significant problem to secondary school learners, especially those in historically disadvantaged schools. The benchmark against which map use performance is measured is the school leaving geography practical examination introduced during the 1970's which assesses the ability to use aerial photographs, orthophoto maps and topographic maps. Data released recently by the State Information Technology Agency (SITA) reveals that the problem is ongoing (see section 1.6).

While poor map use performance at school level is decried, very little research into developing solutions to this problem is recorded. At the 1999 conference of the Society of South African Geographers (SSAG) held in Windhoek, Namibia, only one of the fourteen sessions dealt with geography education issues. Two papers dealt with tertiary level geography education, one with the proposed new curriculum for education in South Africa (Ballantyne, 1999). One paper reviewed educational change in schools in the Eastern Cape province (Fox and van der Stok, 1999) and one the role of geography education in developing map literacy in South Africa (Innes, 1999a). At the 2001 conference of the Society at Goudini Spa, Western Cape, six papers dealing with geography teaching were tabled, all except one (Innes and Engel, 2001b) focusing on tertiary institutions. At the 2003 SSAG conference held in Bloemfontein, out of twenty-three sessions there was not a single one dedicated to geography education although a paper on self-instruction and map skills was presented in a related session (Innes, 2003c). There were two education sessions (out of 28) at the 2005 SSAG Conference in Bellville, Cape Town but all papers dealt with adult or tertiary level issues. In the one session (out of 20) on education at the 2007 Conference in Port Elizabeth, one paper (out of seven) focused on the transition from General Education and Training (GET) to Further Education and Training (FET) level and how it impacted on the teaching and learning of Geography (Nxele, 2005).

The Independent Schools Association of South Africa (ISASA) organises an informal geography conference every two years for teachers from the small, well-resourced private and state school community. New developments are discussed and materials are showcased including, at the most recent get together at Bishops Diocesan College in Cape Town, the use of Free and Open Source Software for GIS (FOSS4G) for rapid mapping (Fleming, 2008). Unfortunately the papers are not published nor made available to the rest of the South African geography teaching community.

On the international front, a paper identifying spatial competence outcomes for South African secondary education (Innes, 2005) was presented at the ICA Conference in A Coruña, Spain. Teachers' attitudes to the introduction of GIS in South African secondary schools were reported (Carolissen *et al*., 2006) at a Commission on Geographical Education Symposium before the IGU Conference in Brisbane, Australia, along with a paper on IT in South African geography education by Van der Westhuizen and Richter (2006).

In an eight and a half page review of the state of Geography in South Africa (Fairhurst *et al.* 2003), less than half a column appears under the heading 'Geography in the school environment'. However, of the nineteen issues that the authors raise as requiring attention, five relate to the teaching of Geography at school level; 'an issue that should be investigated at greater depth and one which should call for urgent action' (Fairhurst *et al.*, 2003: 88). Investigations into the development of the new outcomes based curriculum have come to light, some covering all subjects (e.g. Jansen and Christie, 1999; Chisholm, *et al.*, 2000; Maree and Fraser, 2004; Chisholm, 2005) and a number looking at the impact on school Geography (Earle and Keats, 1996; Binns, 1999; Nel and Binns, 1999; Ballantyne, 1999; Van Harmelen, 1999; Le Grange and Reddy, 2000; Beets and Le Grange, 2005; Le Grange and Beets, 2005) and on Human and Social Sciences (Wilmot, 2005). In light of the implementation of a new curriculum for education in South Africa which brings with it sweeping changes to how Geography is being taught and assessed at primary and high school, more discussion about school Geography in academic circles in this country might have been expected, especially considering the implications for resource development and teacher training. It is on this shelf in the research library, the one reserved for post-1994 South African geography education that the author hopes to place a contribution.

1.2 FROM MAP LITERACY TO SPATIAL COMPETENCE

1.2.1 Definitions

Among the many definitions of maps, one that focuses on the use of maps is valuable: 'A map is a device for storing and communicating information about the physical and social phenomenon that are distributed over the earth's surface – a data storage and retrieval system for spatial information' (Campbell, 1984: 2). Definitions for *map reading* are just as many and varied and often depend on what the user needs the map for (Clarke, 2003). Because maps reveal the location of, and relationships between, natural and constructed features and the spaces they occupy on the earth's surface, the ability to read, analyse and interpret maps is generally termed *map literacy* (Innes 1999b). Because a greater variety of spatial information products and delivery media are now available, the term might be expanded to *spatial literacy*. Competence (as inferred from competence-based assessment) is the demonstrated ability of an individual to meet a pre-defined set of general and/or specific outcomes that assessors, students and others can reasonably judge as having been achieved (Wolfe, 1995). The term *spatial competence* is used in this thesis to refer to the demonstrated ability to use spatial information; a full and expanded definition is discussed later in Chapter Five (see Box 5.3).

With the current emphasis on outcomes based education (OBE) in South Africa, learning outcomes are assessed against a range of assessment standards (Department of Education, 2002a and 2003). Once pre-defined assessment standards are met, learners are considered competent. The level of competence depends on levels of achievement when performing specified tasks (Wolf, 1995). An attempt to develop a series of map use tasks with comparable assessment criteria is presented in Chapter Seven. The value of spatial literacy is highlighted by looking briefly at various uses for spatial information.

1.2.2 Value of spatial literacy

Boardman (1983) describes the four pillars of education as literacy, numeracy, oracy and graphicacy suggesting that someone who emerges from formal schooling able to read and write, count, speak effectively and understand graphic images has been successfully educated. The latter encompasses the ability to produce and interpret graphs, charts, sketches, pictures and maps. The ability to use a map is considered an essential life skill in developed countries and yet, as already discussed, studies abound that highlight the difficulties inherent in this task. In the developing world, problems are compounded by poor attitudes to learning and low standards of teaching (Ormeling, 1996b); due to lack of maps or lack of awareness of their existence, spatial literacy is particularly poor (Anderson and Blanco do Valle, 2003).

Kaplan (1973: 78) warns that in dealing with complex, difficult and delicate environmental systems 'we must use much more of what we know, and we must start to know much more very soon'. A key component of that knowing is the size, situation, relief, drainage, infrastructure and settlement of the areas influenced by such systems (Innes, 1999c). Geographic information systems offer a comprehensive framework within which to manage the intricacies of most environmental systems. Both the input data for a GIS and the output management tools they can produce are spatially configured, requiring users to be spatially literate (Innes, 1999b).

The ability to comprehend and use spatial information is becoming increasingly important. In developed countries many government departments of engineering, agriculture and administration have been using spatial information for planning, monitoring and reporting on projects for many years. Applications using GIS for development and resource management are reported from emerging nations especially in Africa (Zietsman, 1999). At the Global Dialogues for Emerging Science and Technology (GDEST) Conference held in Cape Town in March 2008, a wide range of African GIS projects with an environmental focus were reported (e.g. Hicken, 2008; Kasedde, 2008 and Van der Post, 2008). At the FOSS4G Conference held in the same city later in the year, there were once again African projects reported, this time using Free and Open Source Software for GIS in countries such as Ethiopia (Dresden and Trevedi, 2008) and Rwanda (Ciolli *et al*., 2008). In South Africa, GIS applications have increased exponentially since 2000. Very briefly, they range from measuring arsenic and uranium in groundwater (Stadler, 2001) and tracking stork migration (Avian Demography Unit, 2001) to land cover mapping to monitor vegetation change (Wilson and Schröder, 2007) and integrated water resource management (Craigie, 2008). A report on the new South African address standard stresses the importance of advancing spatial understanding to promote various applications that use geo-coded addresses (Cooper and Coetzee, 2008).

Gould discusses the mental images people have of geographic space and links them with decision making, going so far as to say that the human landscape is effectively 'the spatial expression of the decisions of men *[sic]*' (1973: 183). The ability to use spatial information therefore has serious implications for development because the mental maps in the minds of decision makers have serious implications for industrial location, administrative planning and social investment, especially in developing countries. A major hindrance to the widespread use of GIS for development in Africa is the lack of a standardised National Spatial Data Infrastructure (NSDI) in many countries (Clarke, 2008). While it has been suggested that there is sufficient capability in Africa to carry forward the potential of spatial data to support sustainable development, capacity is required in the form of human and material resources and political will (Ottichilo, 2008). Annegarn (2008) has identified the characteristics of successful high-technology sustainable development partnerships between countries in Africa linked with those in Europe and the United States.

Apart from the political and social concepts of land, it remains a spatial commodity being a specifically bounded area or space. Philosophical discourse on perceptions of land and political debate on land rights (Christopher, 2003; Ramutsindela, 2002) can only have practical effect when specific land parcels are identified, surveyed and mapped. It is the diagram of a plot of ground (commonly named an *erf* in South Africa) accompanying the deed document that signifies legal occupation rights (Engel, 2003). In the land reform programme of the South African government some degree of spatial literacy is required by those claiming land, those processing the claims and those administering the process. High level spatial skills are required by those surveying and mapping land parcels, access to training in these skills is therefore vital for all population groups, including those formerly denied adequate education in South Africa (Pateni, 1997b). Apart from GIS applications related to development and environmental responsibility briefly described above, the use of GIS in the provision of utilities and their maintenance has grown rapidly requiring spatial skills of a broad-based work force.

All military activity is focused on space (LaPorte and Melcher, 1997; Unewisse *et al.*, 1999). The space can either be a specific point on the earth's surface or space relative to such a point. In planning or executing an attack or in peacetime intervention during natural disasters, decisions have to be made in relation to spatial information (Jacobs and Smit, 2001). From the highest level of command and control down to the lowest rank, spatial information is vital. In the military context, spatial literacy can spell the difference between life and death.

There has been rapid growth in the location based services industry. Born out of the Global Positioning System of the United States military, this industry provides location information to users ranging from medical researchers tracking the spread of disease to security companies retrieving stolen vehicles (Hurn, 1989). The ability to give pinpoint location to sub-centimetre accuracy (with post-processing) can now be used for rapid mapping without time-consuming traditional survey methods (Turner, 2001). Because the applications continue to expand, the spatial literacy levels of service providers and their staff must improve. Pateni (1997a) stresses that, for GIS to make headway in South Africa, standards of map literacy must be raised and the spatial information fraternity must be open to everyone. If a market is to be found for the potential products of this industry, consumers will have to become more spatially aware and proficient.

It is unfortunate that, just when Africa most needs persons with advanced spatial skills (technical and professional land surveyors), the number of new graduates in this field is at its lowest (Rüther, 2003). In response to the great need for rapid training in spatial skills, the National Mapping Organisation in South Africa has been proactive in establishing the learning outcomes for the courses to be accredited by the South African Qualifications Authority (SAQA), (Hull, 2001). SAQA is integral to the revolutionary changes in South African education that will be discussed in Section 1.5.

1.3 STAKEHOLDERS IN IMPROVING SPATIAL COMPETENCE

1.3.1 The general public and spatial competence

Having reviewed the value of spatial literacy it is clear that being able to use a map is an advantage for members of the general public whether their needs span 'the simple location of places to optimising routing to complex determination of spatial patterns' (Clarke, 2003: 713). The ability to understand the representation of one's local environment on a map leads to more informed decision-making in matters related to land (Berry *et al.*, 2001; McMaster *et al.*, 2001). The reading of road maps may be considered a basic life skill. Walford (1999: 28) stresses that 'maps are vital, but often undervalued tools of everyday living'. Because graphicacy complements literacy and numeracy (Balchin, 1985), the acquisition of map use skills facilitates the understanding of other graphic data such as graphs, flow-charts, plans and photographs. No means of measuring the spatial competence level of the general public has come to hand but, based on the number of maps purchased from the national mapping organisation per head of population, Clarke (1997) concluded that South Africans lagged far behind other countries.

1.3.2 National Mapping Organisations and spatial competence

One important objective of a NMO is to increase the awareness of maps by the general public so as to increase the use of spatial information. In practical terms this will increase sales of maps and allied spatial data products and improve the effectiveness of such organisations. In an attempt to make the inhabitants of Catalunya, Spain aware of the availability of local map sheets, they were printed in the local newspaper over a period of some weeks (Institut Cartogràfic, 1997). Once the low quality newsprint maps deteriorated, map sales increased appreciably because people had started relying on their local spatial information.

In 2002 Ordnance Survey (OS), the NMO of Great Britain, embarked on a unique project to improve spatial competence by giving a free local topographic map to every 11-year old learner. Due to its success as an awareness campaign, the project was repeated benefiting more than 1.5 million scholars. According to Schools Minister, Stephen Twigg, the project also has great educational value 'because the maps will be theirs to keep, they will be able to learn much more about their local environment both in the classroom and at home with their families' (Ordnance Survey, 2004: 16).

The NMO of South Africa is the Chief Directorate of Surveys and Mapping (CDSM) which falls under the national Department of Land Affairs (DLA). Training in spatial skills has been a priority of this organisation since its inception in 1920 (DLA, 2000). The NMO launched a Map Awareness and Map Literacy project in an attempt to increase their client base and improve map use performance (Hanekom, 1998). This five-year project, named MapAware, ran from 1997 until 2003 and had two objectives: one was the improvement of map use competence among adults; the second was to improve the map use competence of learners still at school (Innes and Engel, 2001a and 2001b). Both initiatives ran concurrently sharing the development of learning materials for map use.

- The MapAware Adult Education Project

A one-day map skills workshop programme was developed to introduce basic map literacy to adults (Innes, 1997). This was extended to two days when participant evaluations indicated that too much information was being imparted with too little opportunity to practice new skills (DLA, 2000). While the initial concern of the MapAware Project was the general public, the need for improving map skills to expedite the Department of Land Affairs' Land Reform programme soon became its focus (Engel, 2002). Although South Africa is well mapped (Clarke, 1997) the majority of departmental staff and their land claimant clients who needed to use maps were unable to access the information that maps contain. Pre- and post-intervention assessment showed that the majority of workshop participants significantly improved their performance when doing basic map use tasks (Innes and Engel, 2001a).

At the end of the five year MapAware Project, its initiatives were absorbed into the Client Relations Management Unit of the Sales and Marketing Department of the NMO. The general introductory map skills workshops have been complemented by advanced workshops that deal with the legal implications of surveying, deeds and land rights (Engel, 2003). The adult learning programme depends on intervention by at least two trainers with small groups of adult learners (maximum 20). Although a highly effective methodology, costs are high. The small numbers that can be taught efficiently per intervention and the limited number of skilled trainers makes general improvement in spatial literacy a slow process.

- The MapAware School-based Project

While investigating how changes to the topographic map symbols impacted on map use teaching, the difficulties experienced by geography learners in relation to maps were discussed with the NMO (Innes, 1995). Soon afterwards plans were revealed for making the general public more aware of maps (Clarke, 1996). A year later those plans were being implemented with the design and production of learning materials (Innes, 1997). In order to intervene before adults enter the workplace without adequate spatial skills, the MapAware Project made provision to support the teaching of map use skills at school level (Tickner, 2000). The MapPack initiative was launched in 1997 to provide, free of charge, five local topographic maps to any school offering Geography to the twelfth grade (Innes and Engel, 2001b). By 2002 almost 3 000 topographic map sheets had been supplied to schools. The project is on-going but unfortunately no investigation of the classroom use of the maps has been undertaken.

The publication of *MapTrix: a self-instruction programme for learning to read the 1:50 000 topographic map of South Africa* (Innes, 2000), was sponsored by the DLA and 2 000 free copies were distributed by the NMO (a full report on the distribution and evaluation of these learning materials is contained in Chapter Three). By making maps and learning materials available to teachers it was hoped that map competence could be improved. Further publication and distribution of *MapTrix* by the NMO was terminated at the end of the MapAware Project's 5-year term but the publisher that had originally won the tender agreed to continue publication.

1.3.3 Geography at tertiary level and spatial competence

The history of school geography teaching (outlined in Section 1.4) reveals how the past lack of equity in education has resulted in the markedly different spatial skills development of South Africa's population groups (Liebenberg, 1998). In an education system where '...the greatest attention...is placed on the overall pass rate' (Faller, 2004: 8), a useful measure of spatial competence is the mean result (percentage mark) of the practical paper for the Senior Certificate Geography Examination, as discussed in Section 1.6.

Prior to 2007, at the end of twelve years of schooling, learners wrote the Senior Certificate examinations in a minimum of six subjects. If the examination scores in the subjects were high enough and the subjects had been taken at the appropriate grade (at least four on higher grade) then the Senior Certificate was issued with Matriculation endorsement. This indicated that the candidate could proceed to tertiary study without writing a further university entrance examination (Faller, 2004). In 2008 a new examination structure was introduced, which is discussed in Chapter Two.

'The target set by the Department of Education for access to higher studies is over 20 percent of school-leavers. The number obtaining the required endorsement is falling increasingly short of this' (Faller, 2004:9). The school sector thus becomes a stakeholder in improving performance, including performance in spatial competence. Tertiary education institutions often assume higher entry-level skills than the students can demonstrate (Chamberlain, 1995; McGee *et al.*, 1995). Bridging or academic support programmes place increased pressure on tertiary institutions (Faller, 2004). If these skills could be improved at school level, such programmes could be curtailed. Map use is not confined to geographic investigation but features in all areas of study dealing with land and resources. By implication, it is not only the geography departments at tertiary learning institutions that have a stake in the improved spatial competence of first-year students.

1.3.4 Other parties concerned with spatial competence

Any employer requiring staff to use spatial information as part of their line function could become a stakeholder in improving spatial competence. These might be in the public sector such as the South African Police Services (SAPS) or National Defence Force (SANDF) or public service authorities from local to national level. In the private sector from truck drivers to company directors can make better decisions if they have access to relevant spatial information products and the skills to use them. The Geo-Information Society of South Africa (GISSA) which represents the interests of the geospatial information industry actively promotes education, organising GIS Week activities and developing teaching resources to help teachers introduce GIS to their geography classes (Martin, 2008).

1.4 HISTORICAL REVIEW OF MAP USE TEACHING IN SOUTH AFRICA

Having noted the value of spatial literacy and the role of some stakeholders in promoting the improvement of this competence in South Africa, the history of map use education is reviewed to explain the current low levels of map literacy in South Africa.

1.4.1 Sources of historical information

Because it is in geography classrooms that map use is traditionally taught, it is necessary to trace the history of geography teaching in South African schools in order to reflect on the development of map use education. Clark's (1989) review of 150 years of Geography as a school subject is particularly helpful although much of the detail of that history was available for the White population group only. Kallaway (1984), and many since including Nel and Binns (1999) and

Chisholm *et al*., 2000), have outlined the grave problems associated with the education of Black[1] South Africans. Wesso and Parnell (1992) have thrown some light on the history of geography education in South Africa with a strong political focus. It was under the dark cloud of apartheid education that the author first became aware of the map use problem in disadvantaged geography classrooms while tutoring in-service teachers registered for up-grading courses (further reference in Chapter Six).

1.4.2 Early school Geography – separate colonies, Union in 1910, Republic in 1960

Although Geography was introduced into the curricula of English schools in the Cape Colony in 1839 (Clark, 1989) it was only in 1913, some time after the Boer War, that a syllabus was proposed for the matriculation certificate; a major portion 'consisted of the geography *[sic]* of the British Empire' (Wesso and Parnell, 1992: 188). The latter researchers report that acceptance as a university discipline came in 1916 and two years later Geography was established as a matriculation subject in the Cape. The subject proved very popular at secondary school with pupil numbers initially growing faster than any other subject. By 1960 however, the percentage of pupils selecting Geography as one of their matriculation (school leaving certificate) subjects had dropped to about 25 % (Wesso and Parnell, 1992).

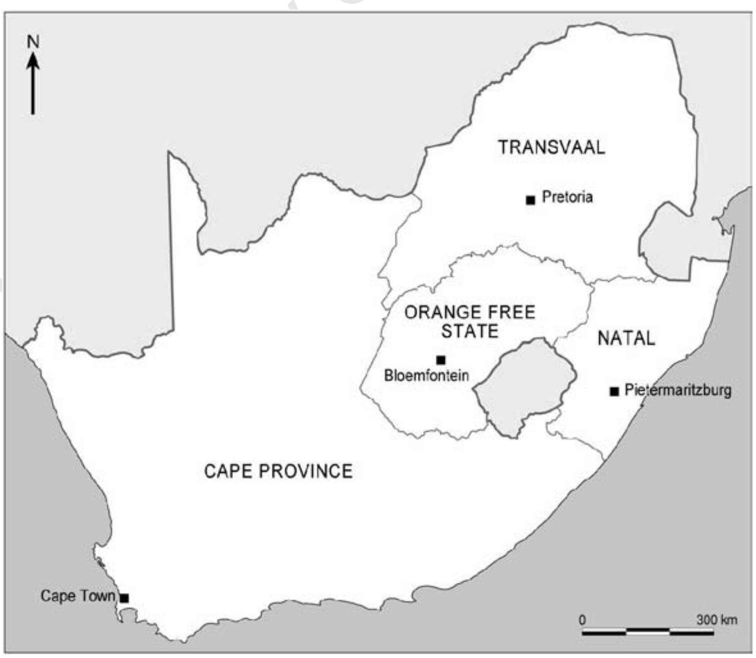


Figure 1.1 Map of the four provinces of South Africa from 1910 to 1994 showing provincial capitals

[1] Apologies are made for the unavoidable use of culturally inappropriate terminology. Terms such as Black and Coloured have been used in the text where necessary in a historical context to identify different groups of people of colour in accordance with former apartheid education policies.

In the Natal colony, later to become another of the Union of South Africa's four provinces (see Figure 1.1), Geography had been taught at primary schools for some time but became a compulsory subject when the first syllabus was introduced in 1875 (Clark, 1989). In 1921 it was established as a degree subject at the University College of Natal, setting the stage for rapid expansion at secondary school level. By 1966 all high schools in the province offered Geography with 68 % of candidates writing the subject for matriculation examinations - the highest in the country (Clark, 1989).

In the Transvaal, progress was much slower. Geography was introduced in the mid 1800's but dropped by the turn of the century. In 1904 the colonial power reintroduced the subject 'following current British practice' (Clarke, 1989: 48) but by 1966 only 21.5 % of candidates offered Geography for matriculation. Geography in the smallest of the provinces, the Orange Free State, followed the pattern of the Transvaal and by 1966 although only half the high schools offered the subject, 25.3 % of all candidates selected the subject for matriculation.

While the previous paragraphs serve a chronological purpose in tracing the early progress of Geography in schools for White children, the narrative does little to highlight the plight of the majority of learners of other skin colours; the spurious basis for differentiating the education offered to them. Clark (1989: 48) describes the situation as follows:

> 'The introduction of the subject to other groups was impeded by inadequate funding, a chronic shortage of specialist teachers, a short school life, problems related to the language of instruction, and a belief that a restricted curriculum, offering less range and depth, was more appropriate for the 'needs' of particular groups.'

Geography was taught in a piecemeal fashion to different population groups. Initially many mission schools offered the subject at primary school level but Clark (1989) reports that in 1956, History Geography and Nature Study were grouped as Environmental Studies in the first three years of primary school and that Geography was included with History, Citizenship, Safety Rules and Vocational Guidance in Social Studies for school years four to six. In 1967, Social Studies incorporating Geography, History and Civics became a compulsory subject at schools for Black learners in years seven to nine. Very small numbers of pupils of colour completed the twelve years of schooling required for matriculation (Kallaway, 1984). The small proportion that selected Geography at this level followed the same syllabus (with minor changes) prepared for White learners.

1.4.3 School Geography in South Africa from 1970 to 1990

A review of changing geography syllabuses and provision for map use teaching from 1839 until 1970, when the National Party's apartheid style government was well entrenched in South Africa, can be found in Appendix 1.1. Starting in the early seventies, attempts were underway to bring South African Geography into line with European and North American developments, calling for '...a major shift in tertiary geography curricula to include more mathematics and science....as a wave of positivist fervour irrevocably challenged...research and teaching agendas' (Wesso and Parnell, 1992: 193). The real impact of a more scientific approach to Geography was only felt in geography classrooms when a new syllabus was introduced in 1973. Based on a core syllabus adopted for all provinces, it was an attempt to address a lack of equilibrium that had resulted from uncoordinated periodic changes in the provinces during the previous phase (Clark, 1989). The Committee of Heads of Education (CHE) and the Joint Matriculation Board (JMB) selected for this core the Cape Senior Syllabus for Geography, which had been revised and updated twice, in 1964 and 1966 (van der Merwe, 1982).

The 1973 syllabus was a radical departure from what had previously been offered in some provinces. It was also a first attempt to get consensus from various interest groups and stakeholders in geography education. Although a general improvement was acknowledged, it is not surprising that much criticism followed its introduction (Clark, 1989). Significant features were the marked reduction of regional geography and the inclusion of systematic studies of climatology, geomorphology, population geography, economic geography and settlement geography. A second examination paper for practical work was introduced at this time to assess map reading, analysis and interpretation. This was a significant step in fostering the teaching of map use skills in South Africa.

It was also during this phase that resentment towards segregated education for people of colour built up, eventually leading to the Soweto Riots, school boycotts and the near collapse of Black Education. In response to the education crisis of the 1970's and 1980's the Human Sciences Research Council (HSRC) Commission of Inquiry into Education was called into being with 'a brief to provide recommendations for an education system which would meet the manpower needs of South Africa and provide education of 'equal quality' for all population groups' (Chisholm, 1984: 389). This did not, however, mean equal education as a 1983 White Paper still defined education as the responsibility of each of the population groups falling under the tri-cameral constitution for

Whites, Coloureds and Indians. These population groups were given responsibility for their own education because this was considered one of their 'own affairs' (Hofmeyr and Buckland, 1992).

Education of Africans was still regarded as a 'general affair' falling under the White-dominated parliament. Chisholm (1984) notes from the HSRC report that, for the first time, free basic education for Black pupils up to approximately twelve years of age was recommended. Post-basic education should be state funded for those following vocational/technical training but parents would have to fund their children's schooling if they chose the academic option. This was generally only available to Blacks at expensive, multi-racial private schools, to which access had previously been prevented by apartheid legislation. Although not all aspects of the recommendation were accepted, a provisioning programme followed including the building of schools and colleges and improved teacher training (Hofmeyr and Buckland, 1992). However by 1989, the deprivation of decades of apartheid education could still clearly be seen (Table 1.1). The high pupil-teacher ratios, high percentage of under-qualified teachers and low per-capita expenditure on Black learners clearly accounts for the low general pass rate at Senior Certificate level. These factors are compounded for geography learners because of the technical nature of the skills associated with map use.

Table 1.1 Comparative education statistics 1989 (after Hofmeyr and Buckland, 1992: 22)

	White Education	Indian Education	Coloured Education	African Education
Pupil-teacher ratio	17:1	20:1	23:1	38:1
Under-qualified teachers*	0 %	2 %	45 %	52 %
Per capita expenditure	R3 082.00	R2 227.01	R1 359.78	R764.73
Matriculation pass rate	96.0 %	93.6 %	72.7 %	40.7 %

*Qualified teachers have 12 years of schooling with 3-year teaching certificate

Despite the general problems in education, Geography showed considerable growth during this period. Pupil enrolment with the largest education department, the Department of Education and Training (DET) for the final school examination in 1976 was 7 529. By 1984 this had risen to 63 488 (Ballantyne, 1987b). This represents an increase of 743% over eight years. While this probably reflects the general increase in pupil numbers as much as a preference for Geography above other subject options it still highlights the demand for more map use education. Expenditure on education increased rapidly with much of the focus on vocational training. Unfortunately, Geography as a school subject and thus map use education for the majority of learners received little benefit from these positive changes.

A revision of the 1973 syllabus, intended for implementation from 1985 in the Transvaal, stipulated that Geography was compulsory up to the ninth year of schooling. The subject was then offered as one of the electives for the matriculation examinations. The syllabus objectives were devised to impart geographical knowledge, develop skills, improve perception of the environment and encourage appraisal of actions that impact on the environment. The skills to be developed were oracy and literacy, numeracy, graphicacy and interpretation, and fieldwork techniques. It was accepted that graphicacy and interpretation skills are both developed by mapwork, which 'should be integrated with every section of the syllabus' (Transvaal Education Department Syllabus, 1983: 10).

1.4.4 South African Geography education in the early 1990's

Internationally, threats to the status of Geography had led to serious reconsideration of its role, especially in education. As a result of these deliberations, the Commission on Geographical Education (IGU, 1992) issued the *International Charter on Geographical Education*, which demonstrated how the subject contributes to individual education, international education and environmental/development education with a strong emphasis on knowledge and skills related to place and related spatial issues. It is in the spirit of this charter that the content of the geography syllabus and the provision for the teaching of mapwork changed significantly during the 1990's

Turner (1993) notes that, while 70 % of matriculation geography candidates were White in 1970, by 1992, 70 % were Black. The geography curriculum in use in the early 1990's was considered to be irrelevant for many learners on account of it having been developed in a 'white- and male-dominated process which had been non-participatory for the majority of role players' (Kriel, 1993b: 14). Despite the fact that education generally was regarded as lacking political legitimacy (Conacher, 1993), the popularity of Geography as a school subject continued to increase amongst Black learners. Comparing the 1992 and 1993 examination statistics for the DET (including the homelands and former self-governing territories of Transkei, Bophuthatswana, Venda and Ciskei) shows an increase of 19 737 geography candidates in one year (DET, 1992 and 1993).

Major changes were taking place in South Africa. 'The division of education into racial compartments both at school and college of education level, was meant to strengthen the attempts to separate education from politics, but, in the process, this division created a situation where the reverse of what was intended resulted and education has(d) become a political tool' (Conacher, 1993: 28). On the eve of the first democratic elections in South Africa it was imperative to instil new faith in an education system that would serve the needs of a politically free South Africa.

1.5 THE NATIONAL CURRICULUM MODEL AND GEOGRAPHY

The review in the previous section of geography teaching in South Africa and concomitant map use education highlights the great disparity between various population groups. A change in politics cannot change classroom realities overnight. Despite the dismantling of apartheid, the divisions between more and less privileged learners remain, now marked less by skin colour than by the language of teaching and learning, parents' earning capacity and core-periphery differences. A major initiative to try and bring all learners into an equitable learning environment was a unified education model (Chisholm, 2005).

1.5.1 Development of a National Curriculum Model (C2005)

Kriel (1993a) traced the process of drafting a new curriculum model for pre-tertiary education in South Africa starting in 1989. The Committee of Heads of Education Departments (CHED) involved a large group of people including experts as well as representatives from within and outside education circles. A discussion document was released in 1991 and circulated widely for comment. The proposal to join History, Geography and Economics into one subject was rejected. A second and then a third discussion document were released each encompassing comments arising out of the participatory process.

In looking at the potential of Geography as a school subject in the new curriculum model, Fairhurst (1993) considered four focus areas to be important: Geography as a bridging science, the holistic and the enquiry approaches, environmental issues and environmental education. She suggested that Geography should meet the needs of a changing society but, while acknowledging that the Human Geography emphasis was spatial, she made no specific reference to the role of map use in the new model. Kriel (1993a, 1993b) outlined the threats and opportunities, which this model posed for Geography. Agreeing with Fairhurst on the matter of environmental education he further urged that Economics and History be incorporated into the geography curriculum. He was concerned that the 'affective domain of learners' development was neglected in the past and should receive serious attention in a new curriculum for Geography' (Kriel, 1993b: 22) and that research-orientated fieldwork studies should be used to create learning experiences for learners. Acknowledging that much of the content that was being taught in the classroom was outdated, Turner (1993) suggested that the skills being taught were not helping pupils either at tertiary level or in the job market.

While work had started on the new curriculum model (C2005) for national education, eventually to be adopted by all population groups, the Department of Education and Culture had completed a syllabus revision aimed initially for implementation in schools for children classified under apartheid legislation as Indian. This included a new Core Syllabus for Geography. Although there was little change in content, the *Working Document for Geography* (Department of Education and Culture, 1992), prepared for implementation from 1993 onwards, stressed the importance of spatial concepts taught through the medium of mapwork. The section for each school year opened with the reminder that mapwork formed the basis of Geographic studies. This syllabus was also an attempt to engender tolerance and reduce the divisive influence of the government's policy of Christian National Education (Wesso and Parnell, 1992). Positive aspects of this document were later incorporated into the new curriculum model.

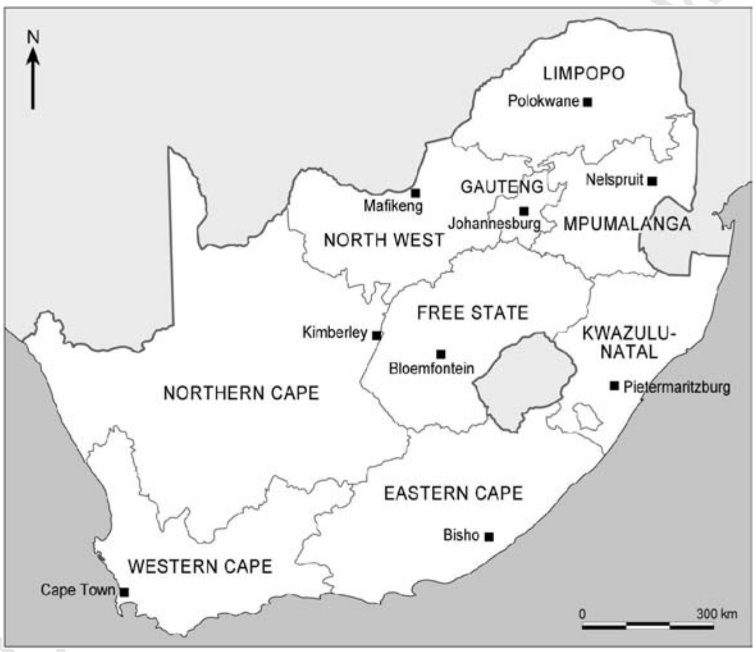


Figure 1.2 Map of South Africa showing the post-1994 division into nine Provinces (with provincial capitals)

The 1994 elections saw the dissolution of the four provinces, the tri-cameral parliament and the infamous policies of the DET. The country was divided into nine provinces (Figure 1.2) reincorporating Transkei, Bophuthatswana, Venda and Ciskei (formerly known as the TBVC states) and various other areas previously designated as homelands. Although education provision became the responsibility of each province, it took some time to dismantle the various examining authorities that had previously existed and put into place new policies dictating that children of all race groups should have equal access to equitable education. Starting in 1996 all school leavers, irrespective of skin colour, wrote the same provincial school leaving matriculation examinations for all subjects

(Le Grange and Beets, 2005). The new education policies of the post-apartheid government took full effect only once the National Curriculum Statement (NCS) for FET level, implemented in Grade 10 in 2006, culminated in a common national examination for all learners in Grade 12 in 2008 (Beets and Le Grange, 2005).

1.5.2 Curriculum reform within the National Qualifications Framework (NQF)

The curriculum model is divided vertically to accommodate successive years of study including pre-school, school and tertiary education and horizontally to include twelve knowledge fields linked to occupational categories. It was important to put an overall framework into place before individual subject areas could be finalised. The structure was linked to qualifications and became known as the National Qualifications Framework (Table 1.2). Core Syllabus Committees (CSC's) were formulated to assist with subject curriculum development (Kriel, 1993a). The CSC responsible for Geography held their first meeting in 1993 at which the *International Charter on Geographical Education* (IGU, 1992) was evaluated as a point of departure.

Table 1.2 The National Qualifications Framework (NQF)

National Qualifications Framework NQF	**Education (Grades = number of years at school)**	**Training**	**Three Education and Training Bands**	**Qualification Type**
Level 8	12 + 6 or more	SAQA accredited technical diplomas and degrees	Higher Education and Training (HET) Band	Research
Level 7	12 + 4 or 5			Higher Degrees
Level 6	12 + 3 or 4			Initial Degrees
Level 5	12 + 1 or 2			National and Higher National Diplomas
Level 4	Grade 12	Wide range of vocational training courses, SAQA accredited	Further Education and Training (FET) Band	National Certificate (C) (FETC)
Level 3	Grade 11			
Level 2	Grade 10			
Level 1	Grade 9	ABET* 4	General Education and Training (GET) Band	National Certificate (C) (GETC)
	Grade 8			
	Grade 7			
	Grade 6	ABET* 3		
Compulsory schooling	Grade 5			
	Grade 4			
	Grade 3	ABET* 2		
	Grade 2			
	Grade 1			
Reception year	Grade R	ABET* 1		

*Adult Basic Education and Training

	Primary school		Overlap between primary school and GET band		Secondary school

(Adapted from SAQA, 2000, 5)

Many meetings and much deliberation followed (Chisholm *et al*., 2000). Fairhurst (2002) comments that '...the SAQA issue has not been without anxiety, pain and concern'. By 1995 the investigation into an alternative education system for South Africa led to the adoption of the National Qualifications Framework (NQF) bill. The bill was passed into law as the South African Qualifications Authority (SAQA) Act (No. 58 of 1995). This framework lays down educational outcomes for a range of core learning areas from the reception year (Grade R) to Grade Nine when the General Education and Training Certificate (GETC) can be awarded. Similar certification is available to adults who follow the Adult Basic Education and Training (ABET) programme.

1.5.3 The National Curriculum Statement (NCS) for Geography and the school system

A draft statement on the national curriculum was published in 1997 and comments were called for (Ministry of Education, 1997). While many positive aspects of the *International Charter on Geographical Education* were incorporated, by the end of the drafting process Geography had been fragmented, with most content and skills falling into two of the eight learning areas of the curriculum for the General Education and Training band, the Natural Sciences and the Human and Social Sciences. There was little emphasis in developing spatial competence. Complaints about Geography and other subjects were received (Ballantyne, 1999; Binns, 1999; Van Harmelen, 1999) to which the policy makers in the Department of Education (DoE) responded (DoE, 2002a). While work continued on preparing a draft statement for Grades 10 – 12 which would lead to the Further Education and Training Certificate (FETC), a revision of Curriculum 2005 for Grades 1-9 (GET level) was called for by a newly appointed Minister of Education, Prof Kader Asmal.

The review process led to the release of the Social Sciences policy document for the *Revised National Curriculum Statement for Grades R-9* or the RNCS (Department of Education, 2002a) in which History and Geography received equal recognition and part of the assessment of the Geography component is based on map skills. Together with the *National Curriculum Statement Grades 10-12* (DoE, 2003) released the following year, they prescribe what is currently taught in geography classrooms in South Africa. These documents, and others released since, are the focus of the discussion at the end of Chapter Two where an attempt is made to reveal their potential for developing spatial competence within the school system.

1.5.4 The NQF, FET Colleges and HET institutions

Parallel to the school system (as illustrated in Table 1.2) FET Colleges offer a range of specialised or focussed programmes to out-of-school youths and adults. Some of these have an academic orientation but most prepare examination candidates for entry into the workforce or further vocational training under the joint supervision of the Department of Labour (DoL). These institutions have an important role to play in meeting the objectives of the NQF in relation to redressing the skills shortage in the country and tackling unemployment (DoE and DoL, 2002).

The objectives of the National Qualifications Framework are to:

- 'Create an integrated national framework for learning achievements.
- Facilitate access to, and mobility and progression within, education, training and career paths.
- Enhance the quality of education and training.
- Accelerate the redress of past unfair discrimination in education, training and employment opportunities, and thereby
- Contribute to the full personal development of each learner and the social and economic development of the nation at large' (SAQA, 2000: 4).

Higher Education and Training (HET) institutions include specialised colleges, universities of technology and traditional academic universities. With regard to vocational training, SAQA is already registering national qualifications and their component unit standards submitted by various National Standards Bodies (NSB's). Unit Standards are registered statements of desired education and training outcomes with associated assessment criteria (SAQA, 2000: 8). The NSB for Human and Social Sciences registered a Standards Generating Body (SGB) for Geography in December 2004 and work is progressing on the identification and development of Unit Standards for Geography.

The Geographic Information Science SGB has had a *Short Learning Programme in GIS* registered with SAQA which is to be offered by the University of South Africa (UNISA) for the first time in 2009. The course 'will be beneficial to Geography teachers in secondary schools that lack the knowledge and skills to effectively teach the GIS concepts that have recently been introduced in the Grades 10 to 12 Geography curriculum' (viewed 11h32 on 02.07.08 at http://www.unisa.ac.za/Default.asp?Cmd=ViewContent&ContentID=20284).

1.6 GEOGRAPHY MATRICULATION EXAMINATION RESULTS (2000 – 2007)

1.6.1 Availability of examination scores

While the new curriculum model was being prepared for implementation, annual school leaving examinations continued to be written. Although now written by all candidates, these were based largely on the syllabuses that had been in place for White learners in the four original provinces (Figure 1.1). Anecdotal evidence from various geography teachers, subject advisors and examiners suggested that poor scores for the practical paper brought overall geography examination scores down. To investigate this assumption further, the geography examination data from the National Department of Education were requested. While such data had previously been difficult to obtain, the State Information Technology Agency (SITA), operating under the Promotion of Access to Information Act (No. 2 of 2000), (Government Gazette, 2000), readily released the data which throw light on the balance of scores between the two examination papers.

During the 2000 to 2007 period under review, learners were offered the option of writing their matriculation examinations at either Higher or Standard Grade. (Since 2008 this option is no longer offered). The grades are distinguished by the different focus on questions requiring recall, analysis or interpretation answers. The Standard Grade paper was weighted towards recall and the Higher Grade paper weighted towards interpretation and analysis. Candidates had the same amount of time to complete the two examinations but the Standard Grade exam was out of 300 marks while the Higher Grade exam was out of 400. Since 2006, all provinces have been using the same breakdown of marks with the practical paper contributing 25% towards the examination total, although this was not always the case (as illustrated in the table in Appendix 1.2).

1.6.2 Hypotheses and data analysis method

The dataset provided by SITA is extremely valuable and could form the basis of a broad investigation into the standard of geography teaching in South Africa as evidenced by the different numbers of learners taking the subject, their selection of higher or standard grade, trends in the scores for the theory and practical exam papers and much more. However, the data are used here to address only three hypotheses.

(i) Scores for the Geography Practical examination paper (focused on map use) are generally poor.

(ii) Scores for the Geography Theory examination paper are generally higher than the scores for the Practical Paper.

(iii) Candidates' scores improved with time as they and their teachers adapted to the new examination format.

Data were supplied by SITA in an Access database for all geography examination candidates, for all provinces, for the eight year period from 2000 to 2007. They were converted to 18 Excel workbooks using Microsoft Excel 2007 in which Higher Grade and Standard Grade examination levels were distinguished from each other for each of the nine provinces. Results for the theory and practical papers were listed for each of the eight years and the following data extracted – count, average, standard deviation and variance. Only those candidates for whom examination results were available for both examination papers were used in the population sample and all examination paper results were converted to percentages rounded down to the nearest integer. Mean scores for the theory and practical papers for each province are plotted alongside the differences between the two papers (Appendix 1.3, Figures A1.1 to A1.9).

1.6.3 Poor examination scores for map use

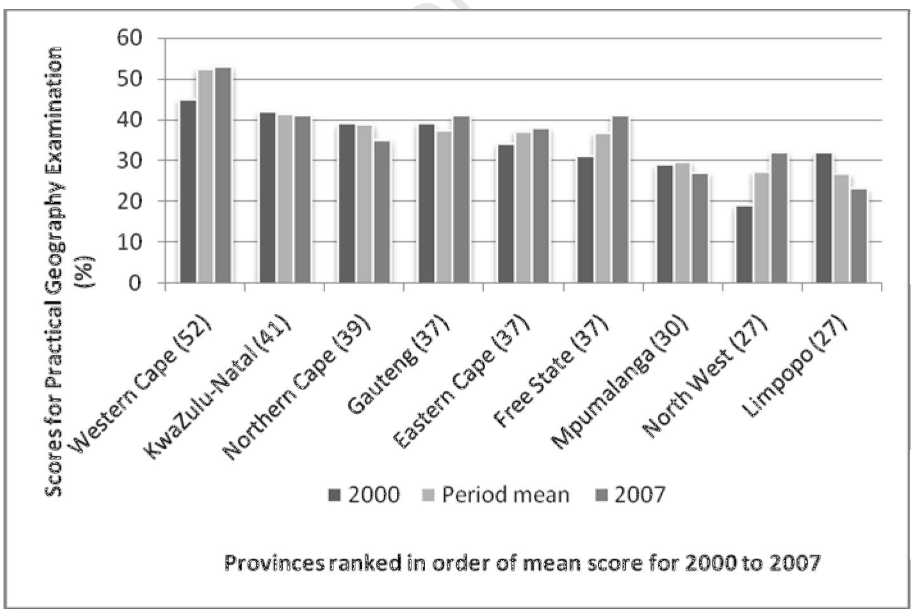


Figure 1.3 Mean scores for the Matriculation Geography Practical examination paper (in brackets) plus scores for the beginning and end of the data period (2000 to 2007)

The pooled mean annual scores from 2000 to 2007 for the Practical paper for each province have been plotted in rank order (highest to lowest) in Figure 1.3 with the mean scores from 2000 and 2007 plotted on either side. From this simplistic representation of the data it is clear that only one province, Western Cape, produced average scores above 50 %. The 2007 mean score is higher than 2000 which indicates an improving trend in this province as well as in Gauteng, Eastern Cape, Free State and North West. KwaZulu-Natal scores have remained almost consistent for the period unlike the scores for Northern Cape, Mpumalanga and Limpopo which show a decline between 2000 and 2007.

While the improved scores in some provinces are encouraging, the fact that only one province has a mean score over 50 %, one a mean score of 41 %, four have scores between 30 % and 40 % and three have scores below 30 % indicates poor results overall. This evidence supports hypothesis (i) that scores for the Geography Practical paper are poor, indicating a wide disparity between what the examiners expect learners to be able to do, using maps and other spatial information, and what they are actually capable of doing.

1.6.4 Comparing the results of the theory and practical geography examination papers

Table 1.3 Comparison of annual mean scores (2000 – 2007) for Theory and Practical Geography Examination Papers at Higher and Standard Grade (based on data represented in Appendix 1.3) indicating the years out of eight when one was better than the other

Province	**Higher Grade**		**Standard Grade**		**Geography examination candidates, both grades (annual average)**	
	No of years (/8) Theory better than Practical Paper	**Count (mean)**	**No of years (/8) Theory better than Practical paper**	**Count (mean)**		
Northern Cape	7	821	7	2 955	3 775	Theory better than Practical
Gauteng	6	13 106	7	21 095	34 200	
Western Cape	5	5 921	6	13 680	19 600	
Limpopo	5	45 761	4	8 677	54 438	
Total						112 013
KwaZulu-Natal	2	22 957	4	28 949	51 906	Practical better than Theory
North West	3	12 459	3	12 063	24 522	
Eastern cape	3	7 667	2	29 936	37 602	
Free State	1	4 502	2	6 258	10 760	
Mpumalanga	1	12 993	1	8 109	21 102	
Total						145 892
Average number of geography candidates per year (2000 to 2007)						257 905

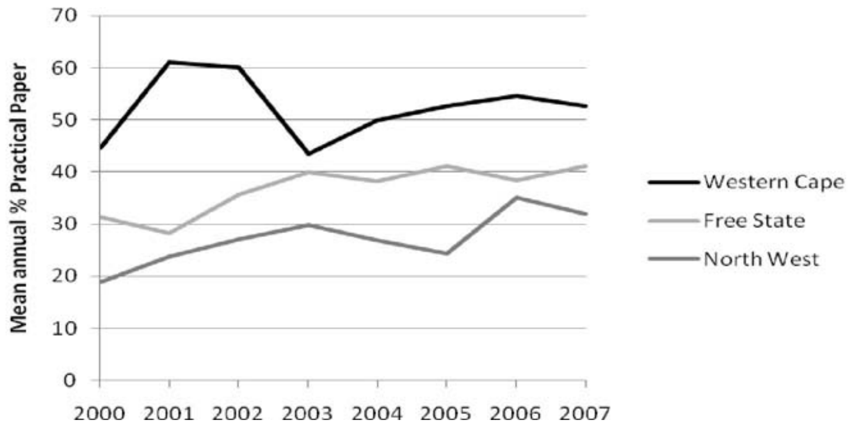
In Appendix 1.3, the scores for each year for the Theory and Practical papers for each province have been plotted, Higher Grade in Figures A1.1(a) to A1.9(a) and Standard Grade in Figures A1.1(c) to A1.9(c). Beside the mean score graphs, the differences between the scores have been highlighted, Higher Grade in Figures A1.1(b) to A1.9(b) and Standard Grade in Figures A1.1(d) to A1.9(d). The scores for the Theory and Practical Papers were compared per year to establish whether candidates' theoretical knowledge was better than their practical skills; the results are summarised in Table 1.3. In four provinces (Northern Cape, Gauteng, Western Cape and Limpopo) scores for the Theory Paper are generally higher than for the Practical Paper. Between them, these provinces produce annually (on average) 43 % of the total number of geography matriculants whose theoretical knowledge is better than their map skills.

In contrast, there are five provinces (KwaZulu-Natal, North West, Eastern Cape, Free State and Mpumalanga), together producing 57 % of the geography matriculation candidates, where the Theory scores are not generally better than Practical scores. Because a greater percentage of learners over the study period have fared better on the Practical than on the Theory paper, the evidence does not support hypothesis (ii) that scores for the Geography Theory examination paper are generally higher than the scores for the Practical Paper.

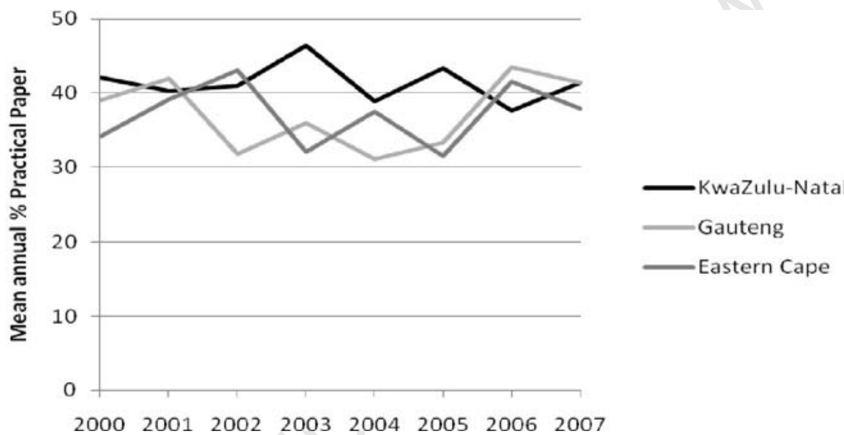
1.6.5 Improved trends in map skills

In an attempt to ascertain whether there was any long term improvement in candidates' map use skills as teachers became more familiar with the changed examination format, the mean annual examination results for the Practical Paper were plotted for the period under review in Figure 1.4 (a - c). Provinces are grouped according to general improvement in map skills starting with Western Cape (period mean of 52 %), Free State (period mean of 37 %) and North West (period mean of 27 %). The three that showed little change were KwaZulu-Natal which maintained an average of 41 % while both Gauteng and Eastern Cape attained a period mean of only 37 %. While Northern Cape scores have vacillated around 39 %, both Mpumalanga and Limpopo scores declined steadily after 2002 leading to a period mean of 30 % and 27 % respectively. The trends only partially support hypothesis (iii) that scores will improve with examination familiarity.

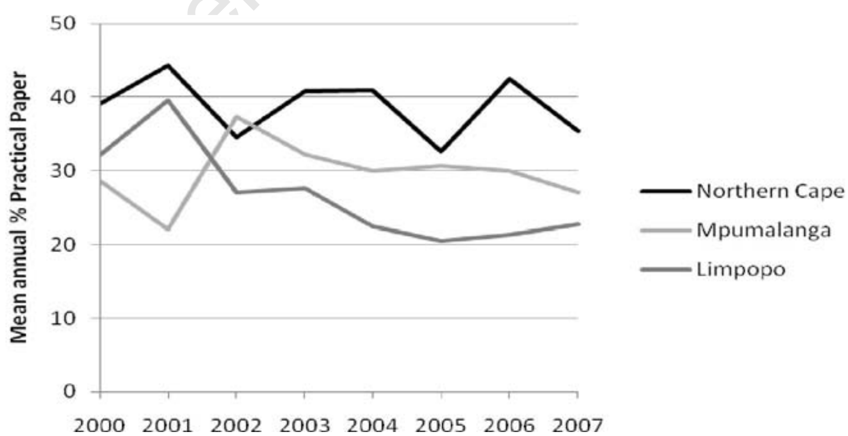
Although it has been shown, contrary to expectations, that scores for the Practical Paper are better than for the Theory Paper in some provinces, rather than suggesting that their map skills are good, the results show that these candidates' mean theory scores are particularly bad. One exception is KwaZulu-Natal where the scores for both papers tend towards 40 % as shown in Figure A1.5 (a) and (c) in Appendix 1.3. There are also some years when the Theory scores are better than the Practical scores in this province (see Figures A1.5 (b) and (d)).



(a) **Provinces with improving scores**



(b) **Provinces with relatively unchanged scores**



(c) **Provinces with declining scores**

Figure 1.4 (a – c) Trends in mean scores for the Geography Practical Paper (2000 – 2007) grouped according to performance during the period under review

1.7 RESEARCH AIM AND OBJECTIVES

That there is a map use problem at school level in South Africa has been established. The historic cause of that problem has been outlined. A literature search will help identify the scope, range and consequences of, and possible solutions to, the map use problem. A clear definition of spatial competence has still to be identified. Generally poor scores for map use in the majority of provinces add a sense of urgency to the need for developing a learning method and concomitant materials to address the teaching of map skills, especially map analysis.

The aim of the research is to develop and evaluate a self-instruction method for analysing spatial information. In order to attain the stated aim, a number of objectives are developed. These are broadly addressed in relation to five key questions and are summarised in Table 1.5.

1.7.1 What is the problem and why does it need to be addressed?

The problem under investigation is the low level of spatial competence of South African school leavers, initially noted during the researcher's experiences while teaching and lecturing Geography. A review of the research literature in the fields of cartography and geography education, while investigating map reading problems (Innes, 1998), revealed that the higher order skill of map analysis also required attention. While school and tertiary educators' complains of students' inability to use maps provided anecdotal evidence, poor results for the geography practical paper in the national Senior Certificate examinations for the years 2000 to 2007 suggest that the problem is very widespread.

The value of spatial information is above question. Tversky asserts that 'spatial knowledge is critical to survival and spatial inference critical to effective survival' (2005: 209). Spatial information is inaccessible to those who cannot read and/or analyse maps. They are therefore unable to reason spatially which means they cannot transform spatial data into something more useful nor make judgements from it. The value of being able to access spatial information in a range of employment opportunities has been reviewed in this chapter, as have the roles of various stakeholders in improving spatial competence.

Now that new geography education policies are in place, which have the potential to improve spatial competence (see Chapter 2.7), there is an opportunity to develop learner support materials to realise this potential. A further reason for addressing the problem is hopefully to maximise the value of research in geographical education by translating the results into useful practice (Gerber, 1996).

1.7.2 What are the possible solution specifications?

The solution to the problem of inadequate spatial competence involves learning, teaching and learning materials (including maps). The development and classroom trial of the prototype self-instruction programme for topographic map reading (Innes, 1998) showed that, to be able to read maps effectively, learners need to i) have a sound framework of geographic concepts, ii) enjoy using maps, iii) work at their own pace, iv) get immediate feed-back and v) practice to improve proficiency. Any advanced skills programme should meet the same learner needs.

From personal teaching experience (and confirmed by Ottosson, 1988 and others) it was found that to be efficient, the teaching of spatial skills should focus on teaching how to use maps not on how maps are made, should recognise and overcome fear of maps and should use local maps to study local issues making map use relevant to learners' everyday experience. What needs to be established is which tasks should be taught, in what order, how should they be taught and how should they be evaluated? The learner support materials should include many examples of a variety of maps and other spatial information products, use active learning to teach how to use maps in real world applications, be enjoyable, allow learners to work independently, give immediate feedback, record progress and ultimately improve map use performance.

1.7.3 What are the appropriate solution options?

When this investigation was initiated (2001) the method of teaching spatial skills in the majority of geography classrooms was probably the traditional talk and chalk approach using textbooks, where available, and possibly additional maps either from previous examination papers or in some cases local topographic map sheets. A survey of resources being used to teach map use was required to throw light on this situation. Until such information was available, various teaching methods were assessed against a range of criteria (Table 1.4). It was against these criteria that *MapTrix* was assessed by the South African Bureau of Standards (SABS) and presented with a Design Excellence Award in the category: education, leisure, sports goods and toys (SABS, 2004: 15).

Table 1.4: Evaluation grid for assessing methods used for teaching map skills

Is the method	easy to access?	cost effective?	easy to use?	novel?	performance enhancing?
Talk and chalk	yes	yes	yes	no	sometimes
Local map study	depends on awareness	yes (if available)	yes (if available)	yes (if available)	yes (if available)
Geography textbooks	yes (if approved)	sometimes	yes	no	sometimes
Map use textbooks	sometimes	no	yes	yes	yes
MapTrix work cards	yes (departmental approval)	yes	yes	yes	yes (in one classroom trial)
Computer based training (using GIS)	not yet generally available	can be (once developed)	can be (depending on software)	yes (if available)	possibly (still to be tested)

The *MapTrix Kit*, developed to teach map reading, meets most of the assessment criteria. Before developing a computer-based training programme using GIS, which is the proposed solution for addressing the map analysis learning needs, more information is required about:

- how map analysis skills might be improved (Chapter Two)
- whether the self-instruction method used for *MapTrix* is broadly effective for a map skills programme (Chapter Three)
- the effectiveness of Geography alone as a means of improving map analysis (Chapter Four)
- the spatial analysis skills that are expected of school leavers (Chapter Five)
- whether resources were available in geography classrooms (Chapter Six)
- the possibility of developing learning materials in collaboration with senior geography teachers (Chapters Three and Six)
- whether teachers were competent to teach the map skills outlined in the National Curriculum (Chapter Six)
- the possibility of using computer assisted training in schools for spatial skills development (Chapter Six).

Once the information relative to the above topics was gathered, then more detailed specifications could be developed for both the process to be used for improving spatial competence as well as the components of the proposed learning and teaching support materials (LTSM).

1.7.4 What is the scope of the proposed solution?

In contrast to much of the research literature consulted, this is not a study of how adolescents understand the real world and demonstrate this by reproducing a map of that reality from their internalised cognition of space (e.g. Downs and Stea, 1973a; Kwan, 1996; Herzig and Jarausch, 2003). Rather, it is a study of their purpose-directed use of maps, assessing whether they are able, with the assistance of a structured learning programme, to answer a series of questions about the places represented on maps and to complete eight specific map analysis tasks using relevant spatial information. First establishing that map comprehension has been attained, the investigation then focuses on a measurable means of assessing an aspect of clearly defined spatial analysis capability.

The specific problem identified for attention is topographic map analysis. It is examined in the context of school-based learning from three angles – firstly, the map in the mind or spatial cognitive development (from Downs and Stea, 1973 to Tversky, 2005), secondly, cartographic maps as representations of the world (with guidance from *inter alia*, MacEachren, 2004) and thirdly, how intelligence is used to perceive, think about and understand the real world (*inter alia,* Sternberg, 2005). Proposed is the development of a subject-based programme (designed learning environment) for teaching an aspect of Geography aimed at improving learners' spatial analysis skills bearing in mind Ritchhart and Perkins' (2005: 777) caution that with any class of educational intervention '...the most fundamental question to be asked is: Does it work – at least with some populations under some circumstances?'

In this thesis the term map is used to include those at all scales, on all themes and made for all purposes, on screen, paper or any other format as long as they display four basic readability characteristics: title, scale, key and position indicator. While all photographs capture images of the environment and can be instructive, vertical aerial photographs are a key resource in both map compilation and geographic investigation and are thus included under the ambit of spatial information, as are satellite images. Improving the ability to analyse any medium that presents a reasonably accurate, vertical view of part of the earth's surface imparting a sense of place and thus containing spatial information is important. But the scope of this thesis is confined to improving these skills at secondary school level where an important prescribed spatial learning resource is the topographic map.

Satellite images are introduced to familiarise learners with an important aspect of GIS technology and are used to illustrate the relationship between the relief of a three-dimensional landscape and its representation on a two dimensional map. These images make an important contribution to geographical study but the technical analysis and interpretation of such images and how they are obtained by remote sensing are outside the scope of this thesis.

Because GIS has been included in the new South African school curriculum for Geography in the practical section on map skills (DoE, 2003 and 2008a), it was selected as a medium of delivery for the learning programme and is assessed in this capacity only. The current literature on the role of GIS in spatial concept development has been consulted where relevant and is discussed in Chapter Two (2.5). There is neither an investigation of the technicalities of GIS software, nor of the variety of software programs used for the virtually unlimited applications of GIS technology. Where appropriate, the map extracts used in the exercises are linked via the GIS software to related thematic maps in the accompanying digital atlas. Because the setting for this investigation is South Africa where it is prescribed for geography studies at school level, the focus is on the 1:50 000 topographic map of this country and related spatial data.

1.8 RESEARCH METHODS

Bereiter and Scardamalia (2007) identify three kinds of research relevant to education:

- basic research aimed at understanding a phenomenon and which is conclusion oriented,
- decision-oriented research which reviews a practice and proposes its rejection or adoption, valuable at a policy level and
- research-based innovation, emerging from the fields of applied science and engineering, which determines whether an innovative approach is fruitful and might be improvable or at least lead to the generation of new findings. Crucial to this kind of research is a full understanding of the nature of the problem.

This investigation falls into the last category.

The methodology used is a mixture of applied research and action research. Applied research 'is that type of study concerned with solving practical problems' (Bless and Higson-Smith, 1995: 154) and emphasises the establishment of relationships and the testing of theories (Cohen and Manion, 1985). Action research, which is always participatory, has the researcher and participants (e.g. the GIS-users focus group in Chapter Five and teachers who participate in collaborative learning materials development in Chapter Six) bringing equal resources and both learning, alternating between action and research (Bless and Higson-Smith, 1995). Many assumptions about the problem and its solution had to be validated or disproved before the main thrust of the research could proceed.

Each chapter of the thesis addresses one or more specific objectives. The methods used to meet those objectives are summarised in Table 1.5. From the outset, the broad hypothesis of the thesis is that the self-instruction method can be used to improve the analysis of spatial information. Action research allows some flexibility to change the parameters of the instrument design and is usually an attempt to solve a specific problem (*low levels of spatial competence*), in a specific setting (*the final three year phase of secondary school*), to meet specific needs (*initially improved school leaving geography examination results, ultimately improved spatial competence*) (Cohen and Manion, 1985). Taking advantage of the opportunity that arose to deliver the learning materials in the GIS environment (rather than as a paper-based package of materials) is an example of research flexibility.

1.9 CONCLUSION

While the research procedure in Table 1.5 may suggest a clear, evenly paced, chronological process, this is far from the reality of conducting such research. Factors that impeded progress included the author's full-time employment with the NMO during the first two years of the project, a commission to join a team of authors who were writing learning materials for South Africa's new geography curriculum and, towards the end of the process, a teachers' strike that delayed the trials by six months. The protracted period of the research spanned two important developments: the implementation of an outcomes-based curriculum for South African education and its revision (DoE, 2002b) and the introduction and rapid growth of geospatial technologies such as GIS, GPS and the worldwide web. Even more recent is the availability of free access to Google's enormous spatial database, GoogleMaps. While the majority of South African learners in rural areas and in poor urban schools do not yet have easy access to this valuable source of spatial data nor to fully operational GIS technology '... it is open to more people in more places on more days in more ways than anything like it ever before in the history of the world' claims Friedman (2005: 177). Due to these developments the focus of the research has broadened. Ultimately, the data analysis and findings reported in Chapter Nine and discussed in Chapter Ten, now relate as much to a relatively low-technology means of introducing GIS into upper secondary school geography classrooms as they do to a means of improving the analysis of spatial information traditionally gleaned from the prescribed study of the 1:50 000 topographic map of South Africa.

Table 1.5 Outline of research procedure

Chapter	Objective	Research method
1	Place the research into context and establish the seriousness of the problem to be addressed.	Literature search, examination data analysis
2	Clarify the terminology, cognitive concepts and means of developing spatial competence and match these with the Learning Outcomes in the new National Curriculum for Geography	Search the literature for guidelines for spatial competence development and review curriculum statements for Geography
3	Evaluate whether the *MapTrix* self-instruction method is effective and whether the programme format is suitable for an advanced skills programme	Conduct a postal questionnaire survey of teachers' and learners' attitudes to MapTrix
4	Evaluate the impact of mathematics and geography teaching on spatial competence	Conduct an experimental case study with school-leavers to compare the influence of their school subject choices on map use performance
5	Identify the spatial skills that are expected of school leavers Formulate the learning outcomes for the programme	Conduct a survey of spatial information industry representatives to • identify and • rank map analysis skills and to define spatial competence
6	Assess the availability of resources for teaching map skills Collaborate with teachers in the development of learner support materials for map analysis Assess the possibility of using computer based training for teaching map skills	Conduct a resource needs survey Conduct a case study in which teachers were invited to participate in the collaborative writing of map analysis tasks. Conduct an informal survey of computer facilities available to geography teachers
7	Identify the design components of a self-instruction programme for map analysis Write a learning programme, based on *MapTrix*, to teach eight map analysis skills Adapt the learning programme for computer assisted training using a GIS platform Produce a prototype map analysis learning programme Trial the prototype of the MapTrix Geomatica programme	Select maps to be used for exercises on eight identified map analysis skills Draft instruction, lesson, exercise and answer texts and assemble illustrative material Instruct the GIS programme consultant to import the required maps into the database Assist the GIS training consultant to adapt the programme text for PowerPoint presentation Develop the assessment instruments (pre-and post-tests and questionnaires) Arrange facilities, find participants and run the trials at four different venues
8	Gather the data to evaluate the MapTrix Geomatica programme from the intervention instruments and the evaluation instruments Evaluate the preliminary map reading programme used to prepare participants for the trials	Encode and enter data from participant information sheets, pre- and post-tests, exercise sheets and opening and closing questionnaires Compare pre-and post test scores for map reading and report results and findings
9	Evaluate: the impact of the MapTrix Geomatica prototype on map analysis skills individual components of the prototype with a view to product improvements the self-instruction methodology	Conduct a statistical analysis of the data from the pre- and post-tests and exercises and compare results to data collected about various participant characteristics and report the results. Conduct a qualitative analysis of the data from the opening and closing questionnaires, compare this to the quantitative data to assess the opinions of participants and report results.
10	Compare results of analyses and review findings in the light of the aim and objectives	Report findings, draw conclusions and make recommendations.

CHAPTER 2
ENHANCING SPATIAL COMPETENCE

The history of the map is intimately linked to the history of Geography itself, representing a means of communicating a stream of geographic thinking.

Benimmas, 2006:78

2.1 INTRODUCTION

Where? is a question that can be answered in many ways. *Where on the map?* leads to a cartographic answer. *Can you explain where?* elicits a cognitive answer. *Where exactly?* reveals actual position or spatial reality. Enhancing spatial competence is an attempt to bring these three types of answer closer together. This does not happen without mental effort. Maps are spatial representations and comprehending representation is an act of mentally intensive knowledge construction (MacEachren, 2004).

This chapter starts with a review of the literature on cognitive maps (mental images of places) followed by a description of the cartographic maps available for teaching map skills in South Africa. Then, literature on how the real world is perceived and understood is consulted. The role of Geographic Information Systems (GIS) in education is examined, starting with how GIS promotes visualisation. The South African geography education policy documents are examined to assess their potential for improving the spatial competence of school leavers. In conclusion the findings of the literature review are discussed to highlight a proposed way in which the image in the MIND, the graphic display on the MAP and the understanding of the WORLD (see Figure 2.1) may be aligned with the aim of improving one aspect of spatial competence – the analysis of spatial information.

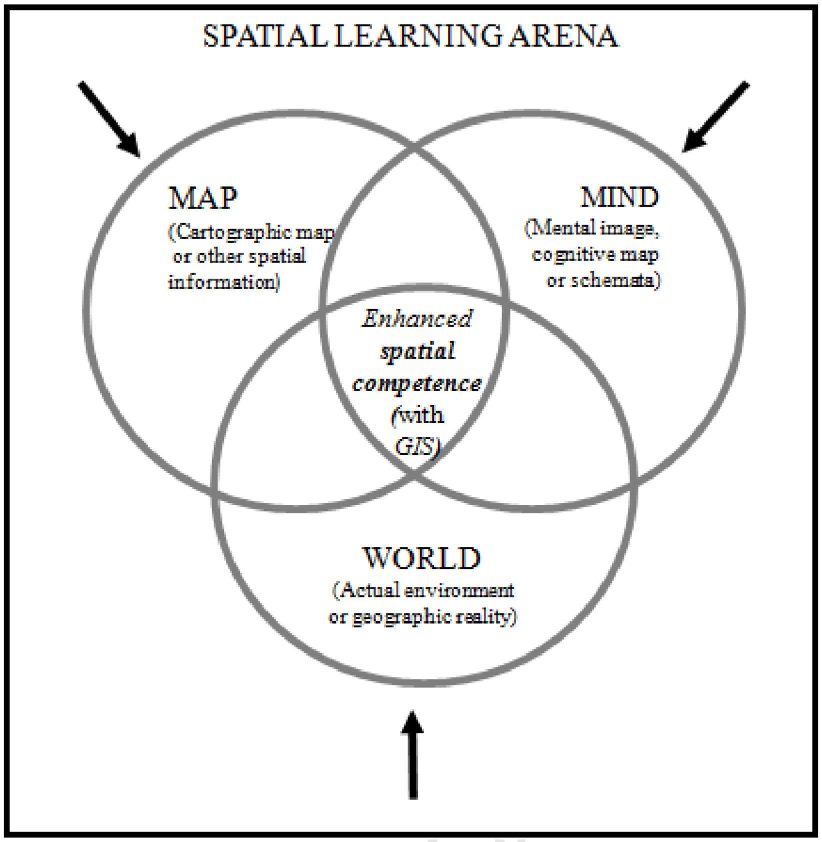


Figure 2.1 Elements of the spatial learning arena: the more that the image in the MIND, the graphic display on the MAP and the understanding of the WORLD can be aligned, the greater the chance of enhancing *Spatial Competence*

2.2 COGNITIVE MAPS

Animal migrations show that being able to move from one place to find another place at a great distance, using some form of mental representation of space, is not unique to humans. Giving expression to that representation is. 'Talk about space and actions in it were probably amongst the first uses of language, telling others how to find their way and what to look for when they got there' (Tversky, 2005: 232). Although language is so closely tied to learning (Fodor, 1980; Gerber, 1984; Okpala, 1989; Butt, 2002) the difficulty of assessing cognitive maps is that they cannot be evaluated in terms of what the investigator can assess via language use, but rather in terms of '...the validity of the map as a guide to the subject in whose head it resides' (Kaplan, 1973: 75) or in terms of maps drawn to represent individuals' cognitive maps, the validity of which has also been criticised (Siegel and Cousins, 1985: 362) on the basis that '...what the researcher records is not the child's behaviour, but rather the researcher's own purposes'.

The term mental mapping has come into use to refer to the paper and pencil exercise of mapping out concepts and ideas (Buzan, 1991; Leaf, 2002). In this thesis, the term mental or cognitive map is used for what Griffin (1973) refers to as a topographical schema, Lynch (1973) calls an environmental image functioning as a decision making tool used to direct movement and Lee (1973) alludes to as a constantly modified model which impacts directly on our spatial behaviour. More recently, Tversky (1993 and 2005) used the term cognitive collage, functioning not just as a facility for storing mental images but as an active facility for judging approximate distances or relative directions between places and then making deductions *on the fly* for the particular purpose at hand.

There is a long history of spatial cognition research which focuses on the importance of landmarks. Siegel and White (1975) advised researchers studying spatial cognition to use large-scale environments where landmarks can be used as visual references to aid route orientation. Cohen (1985), in reviewing spatial cognition research up to the mid 1980's, also stressed the importance of landmarks in how an individual experiences the world (perception) and how an individual understands the world (cognition). Taylor and Tversky (1992 and 1996) found that when asked to describe an environment to be visited, people generally do so by describing a route to or through the area, noting landmarks which will appear either *in front of* or *to the right of* the observer or, taking a vertical perspective, to the north, south, west or east of the observer. They suggested that the latter group, who use direction, have had more opportunity to move around in different environments.

The cognitive map is a representation of the environment that includes direct memories of places visited as well as information from vicarious sources such as verbal or written accounts from others, pictures from print, television or the cinema. All place knowledge is heavily influenced by perceived values attached to those places and the events that occurred there. In places where each cliff and rock, path or plateau has a name and especially if this is woven into local legend and mysticism then people there have a richer, clearer mental image of their environment (Lynch, 1973) and have little use for cartographic maps. While the real world is continuous, for young and inexperienced learners especially, their cognitive maps are discontinuous and made up of only those spaces that have meaning for them with distance perceived according to each individual’s subjective geometry (which is often distorted when compared with Euclidean space).

Although the cognitive map may be influenced by the appearance of the cartographic map, there is no evidence to suggest that, without intervention, an individual's cognitive map has the appearance of a conventional map (Downs and Stea, 1973a; Lee, 1973). Early researchers (such as Boulding, 1973) suggested that errors in map use arise from a mismatch between the cognitive and the cartographic map however, Downs (1985) later called into question the validity of some of the earlier spatial cognition theorists on the grounds that the concept of a cartographic map is no longer a static construct and fellow researchers should '... disentangle (the) understanding of spatial cognition from a presumed understanding of cartography' (Downs, 1985: 342).

For a while, research focus in the area of spatial cognition moved to investigating how visual attention is used to understand map symbols representing both landmarks (point symbols) and thematic data (polygons) (e.g. Lloyd, 1997; Nelson, 2000; MacEachren, 2004) but more recently Bunch *et al.* (2008) have again highlighted the importance of understanding cognitive representation in order to improve map comprehension, especially of digital maps delivered using GIS technology. These technological advances make spatial images available ranging from simple line drawings to sophisticated layered data representations which have dramatically altered the way the world is visualised (as discussed further in Section 2.5).

2.3 CARTOGRAPHIC MAPS

In teaching topographic map skills there is initially a need to convince learners that maps 'stand for' real places. One recognised way of achieving this is to introduce map study using a map of the area where the learning is taking place. This is only possible if local maps are available for inclusion in a programme for enhancing spatial skills. (The selection of maps for the intervention is discussed in Chapter Five).

2.3.1 Supply of spatial information products in South Africa

The Chief Directorate of Surveys and Mapping (CDSM) is mandated by the state to be the custodians of South Africa's spatial information, playing a similar role as other national mapping organisations (NMO's) such as the United States Geological Services (USGS) and Ordnance Survey (OS) in the UK. Apart from establishing 60 000 accurately surveyed trigonometric beacons and town survey marks and a network of active global positioning system (GPS) base stations for facilitating accurate surveying, the responsibilities of CDSM include the planning, data gathering, production, marketing and distribution of the national maps series. This is based on the 1:50 000 Topographic map (1 913 sheets) from which are generalised Topo-cadastral, Regional and Aeronautical maps at 1:250 000 (70 sheets), Topo-admin and Aeronautical maps at 1:500 000 (23 sheets) and at 1:1 000 000, a wall map of South Arica on 4 sheets as well as the 16 sheets of the International Civil Aviation Organisation's World Aeronautical Chart for the southern part of Africa. There is also a 1:2 000 000 wall map of the whole country on one sheet and wall maps of each of the nine provinces at different scales.

CDSM is also responsible for acquiring aerial photography at regular intervals for continuously updating mapping and for maintaining an archive of this photographic material. A series of orthophoto maps at 1:10 000 covers metropolitan and peri-urban areas. Digital versions of the maps at 1:50 000, 1:250 000 and the most recent 1:10 000 orthophoto maps are available as raster images, useful as backdrops in a Geographic Information System (GIS). The major features of the 1:50 000 series are also available in vector format. All digital data are made available at no direct cost.

Cadastral information is the responsibility of the Chief Surveyor General. This includes the approval, plotting and registration of all property diagrams and compilation sheets. The distribution of the Surveyor-General's (SG's) offices still follows the pattern of the pre-1994 provinces (see the map in the previous chapter, Figure 1.1). The Cape Town Office is responsible for the Northern Cape, Eastern Cape and Western Cape (where it is situated). The Pietermaritzburg Office is responsible for KwaZulu-Natal. The Bloemfontein Office is responsible for Free State. For the last four provinces: Mpumalanga, Limpopo, North West and Gauteng, cadastral information is held in Pretoria (Figure1.2). All the map sheets of the national map series related to the provinces they serve are available from these four SG's offices.

Apart from the national map series and cadastral data, other government departments produce maps for various purposes often using national map series data as a backdrop. Examples include the catchment management maps produced by the Department of Water Affairs, population distribution and other statistical maps produced by Statistics South Africa and the town maps and structure plans of local administrations. At least one series of textbooks prepared for the introduction of the National Curriculum urges teachers to acquire as many local maps as possible to facilitate local fieldwork investigations e.g. Beets *et al.*, 2005a, 2006a and 2007a). Probably the single largest commercial publisher of maps available to the South African public is Map Studio, producing a range of maps at different scales including wall maps and street guides for all major cities in the country. Assistance with sourcing maps is available to teachers via their website (www.mapstudio.co.za) and telephonically via their research desk.

2.3.2 Cartographic communication and map use

In order to answer the *where* question effectively, accurate cartographic maps are required at a suitable scale to identify the spatial information about the sites selected for study. A topographic map at a scale of 1:50 000 can provide sufficient information to describe the area including names and positions of physical features (such as rivers, plains and hills), constructed features (indicating settlements and transport links) as well as land use (agriculture, grazing or other economic activities). Orthophoto maps at 1:10 000, which are also very useful for conducting local environment studies, are available for most built-up areas in South Africa. These are ortho-rectified aerial photographic images which are cartographically enhanced by adding place names, feature symbols and contours lines. Although not yet generally available to all schools in the country, because they lack the hardware, software or internet connections to use them, digital data from the NMO and satellite images available from Google (www.maps.google.com), can also provide the spatial component of any environmentally focussed learning activity.

During the flowering of communication theory in the sixties and seventies, cartographers began to see their products as a medium of communication (Robinson and Petchenik, 1975). For cartographic communication to be successful, the reader or decoder of the message is as important as the cartographer, its encoder. For the first time the needs of map readers were recognised and serious efforts were made to address them. Many publications purporting to guide map readers towards an improved ability to use maps simply explained cartographic conventions and assumed that they were supplying the readers with all the tools they needed to understand maps (Muehrcke, 1978). In fact this can be compared with teaching a class how a tennis racket is manufactured and expecting them to go out and play good tennis!

Theories of reading and cartographic communication are summarised in Innes (1998); those that have particular bearing on developing map analysis skills are briefly discussed. According to Gerber (1984: 205) cartographers came to accept that it was their '...ultimate responsibility to minimise the discrepancy between the message intended and the one received'. Smith (1985) on the other hand showed that, the more *behind the eyes* knowledge the map reader has, the fewer *in front of the eyes* clues are needed to make sense of the map, suggesting that it is the map reader's responsibility to be better informed about what they are looking for. The brain takes time to read (understand) what the eyes see (look at). By bombarding the brain with more visual information in an attempt to compensate for lack of prior knowledge, tunnel vision results, effectively blocking the comprehension process. This is a particular problem in using topographic maps where the novice viewer has to create some kind of order out of an apparently chaotic visual array (Petersen, 1985).

To ensure that the novice map user can attach meaning to the elements of the map, a need to know must be created (Guelke, 1979). Because every map user endows the information on the map with different meaning: the secret is to place learners in the roles of different map users, then encourage them to use maps to solve reality-orientated problems. Ottosson (1988) reviewed research into work with children and maps and suggested two important considerations when first introducing maps. It must be ensured that they understand the map symbols and that they use maps of their local area to make the most of their knowledge of the world around them. Sandford (1980, 1986 and 1989) found that when irrelevant tasks are performed in unreal contexts, maps are undervalued by learners. He recommends that map use can best be improved by addressing real issues with local relevance using local maps, agreeing with Naish *et al*. (1979: 49) that all activities in Geography should be '...of direct relevance to the lives of the students, and of significance for the quality of the environment and the welfare of mankind'.

More recently maps are seen more as tools for reasoning about - rather than simply communicating - spatial information. Young (1994: 12) asserts that '...maps are information sources that allow the students to produce questions, furnish arguments, evaluate hypotheses, estimate the value of information and create impressions of places'. Because maps concretize the comprehension of the basic concepts of geography they consequently allow the production of new knowledge.

Benimmas (2006: 77) offers a working definition of geographic reasoning as '...a cognitive process that is composed of the systematic approach to geography, namely description, explanation and generalization, which (is) based on the fundamental concepts of the field and on direct or indirect observation. These operations represent the method by which geographers treat geographic information with the intention of understanding the functioning of geographic space'. She describes maps as tools of geographic reasoning. They communicate the distribution and location of geographic phenomena. They depict what we know of the world because they reflect a cultural message and a social way of seeing and constructing the world. They instigate geographic reasoning by provoking reflection around the questions that arise from maps and by providing their answers. Maps animate the cognitive process that allows for geographic reasoning to occur. This view of maps fits closely with the theory of knowledge building, promoted by Scardamalia and Bereiter (2006) as the 'new pedagogy'.

2.4 UNDERSTANDING THE REAL WORLD

To design a learning programme according to the research-based innovation approach recommended by Bereiter and Scardamalia (2007) it is important to consider new theories of knowledge building (Scardamalia and Bereiter, 2006) as related to how the real world is perceived, categorised and understood. Although cognitive and cartographic maps have been discussed in isolation in the preceding sections, the development of the former and the comprehension of the latter occur in concert. Their mutual relationship to the real world is just as close, cognitive maps being the internalised representation of the world and cartographic maps its externalised representation. Many studies of cognition rely on making subjects draw their cognitive maps. But '...conceptualizing a 3D environment that surrounds us and is too large to be seen at once as a small flat object before the eyes ...(a map)... is a remarkable feat of the human mind' (Tversky 2005: 220) requiring a high level of cognitive ability. Comprehension of the world, starting with the immediate environment and extending to the wider world, depends on cognition (the development of thinking).

2.4.1 Making sense of the real world: theories of cognitive development

Drawing from the work of Kant, Werner and Piaget, Hart and Moore (1973: 286) suggest that '...the concept of space is neither innate nor learned; it is constructed by the child as a series of hierarchically integrated equilibrations through his *[sic]* adaptive interaction with the environment and by means of the reciprocating process of assimilation and accommodation'. Equilibration is putting experiences into relation with one another so as to achieve a system which is stable, consistent and non-contradictory (Piaget, 1964). Such a system Piaget calls a schema (many systems, schemata). Through assimilation and accommodation, experiences are organized into schemata, which are patterns of knowing, and therefore act as guides for appropriate behaviour.

Piaget identified four neuro-physiological stages of spatial development that children go through; these were elaborated by Beard (1969), summarised by Hart and Moore (1973) and revisited by Leat (2002) who refers to these as trends, rather than stages: sensori-motor, pre-operational, concrete operational and formal operational. Infants operate initially in sensorimotor space, their spatial behaviour developing from reflex activity to co-ordinated action, their orientation to the environment is egocentric and while static images may be remembered, there is no evidence of spatial representation. During the period of pre-operational space, children's interactions with their environment have become internalised (through the processes of assimilation and accommodation) and their environmental schema makes it possible to use internal representations of space. Leading up to school going age, topological relations are formed. Egocentric orientation gives way to domicentricity (knowledge of place in relation to the home) and then the use of landmarks and routes. When in this concrete operational stage, the child is able to differentiate between their perspective view (projection) and that of others and they begin to understand Euclidian space (space that can be measured) but they are still unable to manipulate more than one variable mentally and are unable to hypothesise. Having reached the formal operational stage, the young adult becomes more flexible in their thinking about the world '...because situations can be formulated and represented in some symbolic form' (Leat, 2002: 136). It is only in this stage that they can be expected to explain, predict, analyse, synthesise and evaluate. As Treib (1980) argues, there is a vast difference between the world as represented by the geometry of maps and the world as it is experienced. Cohen agrees, noting that '...adults and children alike struggle with this vast difference, with its comprehension and with its representation' (Cohen, 1985: 333).

Piaget's theory of how learning happens by a series of *operations* was interpreted by Naish (1982: 22) with respect to spatial learning and has been adapted below by the addition of examples of map use (author's additions in brackets).

> As children register new experiences (viewing the local map), these are measured against what they already know (visible, familiar surroundings), and *assimilated* into their previous learning (as far as possible). If there is a mismatch between the past and the new experience (such as the perspective and scale), then they will adjust, or *accommodate* the previous learning so as to assimilate the new (find current location from the vertical perspective as a point on the mapped area), thus moving towards *equilibration*. The new learning disturbs their state of mental equilibrium (the change of scale and perspective are not automatic and may be achieved only after some difficulty),

and *accommodation* is compensation for this external disturbance (subsequent understanding of the map with repeated practice eases the disturbance).

How equilibration happens has been the subject of some debate. Some researchers put this ability down to a 'learning mechanism' that somehow improves or matures with the increasing number of new experiences. Fodor threw some light on the problem by arguing that equilibration required the child to evaluate the new learning against existing knowledge that was unable to assimilate or accommodate it. He stressed that it was not the 'learning mechanism' itself that matured but that '...learning is merely a process that uses experience to select among subsets of representational primitives already available to the cognitive system' (Fodor, 1980: 576). These subsets become more and more numerous as the child approaches adulthood and that it is through connections with one or more of these subsets that equilibration is achieved after new experiences have been assimilated and accommodated. In building spatial competence, the broader the young person's frame of geographical reference and the better it is categorised, the more easily they will be able to understand spatial information about places represented on maps. Naish adapted Beard's *Outline of Piaget's Developmental Psychology* (1969) to the needs of geography educators. The capacities of teenaged formal thinkers, as required when analysing and interpreting spatial information, are illustrated in Box 2.1. Relevant mental operations using spatial information are included as examples.

Box 2.1
The formal operations stage

Learners, having reached the stage of formal operations can:

- accept assumptions for the sake of argument (e.g. assuming that a dam wall of given length is built across a river at point x, what will the impact of its construction be on the surrounding landscape?)
- make a succession of hypotheses which they are able to express as propositions to be tested against reality (e.g. calculate the gradient, analyse the vegetation cover and consider the slope aspect of the terrain in area y and assess its suitability for holding a rock concert)
- begin to look for general properties which enable them to give exhaustive definitions (e.g. examine rural settlements on the map and define them according to their pattern of distribution)
- go beyond the tangible, finite and familiar in spatial concepts (e.g. using visualisation, describe the landscape of an unfamiliar place from the graphic display of spatial information on a map)
- become conscious of their own thinking, reflecting on it to provide logical justifications for judgements made (e.g. make and justify decisions about a planned environmental activity using relevant spatial information)
- deal with a wide variety of complex relations such as proportionality or correlation (e.g. calculate the density of a road network and justify it in relation to evidence of economic activity in an area).

(after Naish, 1982)

MacEachren (2004) discusses the role of vision and cognition as part of a map information processing-system suggesting that the eyes initially detect symbols and their relationships to each other, these are interpreted in short-term memory (in relation to the map legend) to arrive at a description of the display. Knowledge schemata are then used to compare the visual impression with knowledge in long-term memory to derive meaning. This may modify existing knowledge schemata or stimulate the creation of new schemata. 'A key factor in map schemata and legend understanding will be the basic human facility for categorizing the world' (MacEachren, 2004: 49).

Studies of intelligence have long included a spatial perspective. Sternberg traced the development of a definition of intelligence from 1921 (in italics in the following quotation) to the present decade: 'Intelligence is *the capacity to learn from experience*, using metacognitive processes to enhance learning, *and the ability to adapt to the surrounding environment*, which may require different adaptations within different social and cultural contexts' (Sternberg, 2005: 751). Spatial visualisation was one of the seven factors of intelligence (or primary mental abilities) that were identified by Thurstone (1938) along with verbal comprehension, verbal fluency, inductive reasoning, number, memory and perceptual speed. The heavy emphasis on the spatial component (the environment) in this definition suggests that the ability to comprehend and work with spatial information makes a significant contribution to being considered intelligent. Gardner (1985) recognises seven intelligences: linguistic, logical/mathematical, spatial/visual, musical, intrapersonal, interpersonal and kinaesthetic. His theory helps identify areas of intellectual weakness and then, using stronger aspects of intelligence, to stimulate those areas previously identified as lacking in effectiveness. Cognitive theorists, including Sternberg (2005: 755), study '...how people mentally represent and process what they learn and know about the world' describing his own theory of intelligence as triarchic: '...dealing with the relation of intelligence (1) to the internal world of the person, (2) to experience, and (3) to the external world' (2005: 763). Sternberg (2005) strongly criticises the findings of Hernstein and Murray (1994) who initially dismissed attempts at intellectual advancement as futile, citing his own work (Sternberg, 1987) and a number of other researchers including Feuerstein (1980) and more recently Wagner (2000) and Grigorenko (2000).

Leat (1997, 2002) discussed ways of raising attainment in Geography, including the ‘Teaching Through Geography’ strategy that was used in England and later in the Netherlands (van der Schee *et al.*, 2003). Success in teaching young learners perception and comparison using the Instrumental Enrichment (IE) approach of Feuerstein is reported by Link (1989). He recommends that geography teaching incorporate, into enquiry-based learning, the principles identified in the Cognitive Acceleration in Science Education (CASE) Project (Adey and Shayer, 1994). These include problem-solving strategies and explicit teaching of concepts such as: variables, relationships, probability and the use of abstract models to explain and predict.

In a situation where choices are influenced mainly by the geography teaching resources available, Roberts (2006) warns that the authors of the most popular textbooks may be shaping the world as perceived by young learners of Geography. However '...whatever we do in schools, students will construct different worlds and develop different geographical imaginations through the interplay between what they learn inside and outside of the classroom' (Roberts, 2006: 376). Drawing on developments in academic geography, there is a noticeable turn towards 'culture' in school geography. The influence of culture on how learners see the world is captured by Freeman (2006: 175): 'This geographical 'World' is also connected to the many Worlds presented to us through the media and popular culture. Then there are the local, personal 'worlds' that we experience and engage with on a daily basis. These worlds are shaped by where we live and who we are and they also influence the way in which we see all that we find around us and beyond'. Morgan and Freeman (2006: 325) suggest that rather than try to standardise the way young people see the world, we should '...explore the benefits and challenges (of) using young people's geographical knowledges, interpretations and preferences to enhance their understanding of, and agency in, the world.' It remains the responsibility of the geography teacher to make learners aware of all possible views of the world and, as far as possible, to make the necessary tools available to them for studying the world.

2.4.2 Measuring the real world: mathematical concepts and spatial analysis

Once learners can read maps with understanding, the next skill level is to analyse the spatial information presented by the point, line and area symbols. Analysis generally implies measurements, patterns and comparisons. Probably the most common error that geography teachers encounter when assessing map analysis exercises is learners' failure to convert map distance to real distance[1]. Downs and Stea (1973a) stressed that while cognitive maps and cartographic maps differ in appearance, three similar operations are executed when moving between each of them and the real world: symbol extraction, rotation of view point and scale change. It is particularly when dealing with map analysis

[1] For example, the question: 'How far is it from the school to the hospital?' will be answered with '7.2 cm'. It is only after explaining that the boy, injured while playing rugby, who needs to be rushed off in an ambulance, is almost 2 m tall that the learners understand the inappropriateness of their answers.

concepts such as distance, bearing and accurate location that the matching up of cognitive map, cartographic map and the real world is imperative.

Naish (1982) lists the most important basic concepts required for logical thinking about the real world as conservation (weight, quantity, volume and number), inclusion (classification of objects according to similarities and differences), seriation (arrange according to size, weight etc) and reversibility (change of perspective or scale of representation does not change reality). The development of the capabilities based on these concepts requires a range of mathematical skills commonly associated with map analysis which in turn require the schemata of formal operational thinking. Naish (1982: 27) cautions that these concepts do not develop at the same rate or sequence and '...that some people reach full development in formal operations very late, and some not at all in certain facets of prepositional thought'.

In claiming that making sense of a complex world is what geography is about, Castner (2002a) put his finger on the map analysis problem. He described map analysis as an unbiased, rule-bound procedure that yields more information from the map than map reading alone, noting that while map reading and map interpretation questions are regularly asked, teachers '...leave out the crucial map analysis step that might help focus the data or lead to new questions and understanding' (Castner, 2002a: 204). He suggests that the reasons that teachers give for avoiding map analysis questions include: they may not know the answers themselves, the issue is too complicated, or, the most damning '...we don't want to bother (or turn off) our students with anything mathematical – when they are older they can learn about those things.' The trouble is that teachers in the higher grades assume that the skills have been taught so they are neglected one again. Having identified the paucity of map analysis teaching, Castner went further (2002b) and described a range of shared mathematical and 'geocartographical' concepts highlighting the value of co-operative teaching between mathematics and geography teachers (discussed further in Chapter Four).

2.5 GIS AND SPATIAL COMPETENCE

2.5.1 Visualisation

While cartographic communication theories focussed on the needs of the map reader as an observer of static paper maps, Eastman (1985) suggests that modern computer-generated maps could be considered as facilitators rather than communicators of spatial information, made possible by human-map interaction. Cartographers roles have changed from producing individual concrete representations to producing systems that provide custom maps in response to user queries using tools that make geographic visualisation possible (MacEachren, 2004). He stresses that rather than passive cartographic communication, the new tools will mean that human-map interaction increases significantly in the process of making spatial meaning and suggests that the reason that GIS is such a valuable tool to geographers is that '...concrete visual displays (can) replace or supplement mental visualisation when information volume and problem complexity makes mental visualisation alone impractical' (MacEachren, 2004, 356). He also showed that by improving map design, visualisation of the reality that is represented can be accomplished with the least amount of effort.

It is not only map design that can enhance visualisation. Just being able to see map detail more clearly when zooming in and out of high resolution scanned map images makes features easier to see and the representation easier to comprehend. A graphic (raster) image such as an ortho-rectified aerial photograph or satellite image can be draped over a Digital Elevation Model (DEM), (also called a Digital Terrain Model (DTM)) rendering a detailed 3D view of the landscape. Vector data layers can be added, such as those used to create a topographic or cadastral map. The transparency of the vector layers can be adjusted so that learners can easily see and identify not just the features represented by the map symbols but also relative elevation and surrounding physical relief. Different thematic layers can be viewed in the same way, instantly providing multiple views of the same location. The rapid pace at which these GIS visualisation tools have been developed and made commercially available has been spurred by military applications and the computer gaming industry (Brooke, 2001); 'fly-through' simulations further enhance landscape visualisation.

The mental visualisation of an area, performed by studying the contours and other symbols on a paper map, is considered a high-level spatial competence, long associated with map interpretation. GIS enabled visualisation tools make it possible to show learners what an area looks like, in considerable detail, while they are still developing what are considered lower-level skills, enabling them to analyse the mapped information with significantly better knowledge of the represented landscape. With reference to Figure 2.1, GIS can significantly enhance spatial understanding because it aligns the image of the landscape that would have had to be created in the MIND, the enhanced graphic display of the MAP and a highly visible virtual WORLD. This in no way removes the emphasis on sound geography teaching's role in studying the real world. McAnneny and Bampton (2006) found that their students' serious misconceptions about Geography and fundamental misunderstanding of the physical world was a significant barrier to GIS learning in courses offered in various disciplines including Geography, Physics, Engineering, Chemistry and Biology at tertiary level.

2.5.2 IT, ICT and the teaching of Geography

Already in the 1960's enquiry-based learning was stimulated with the introduction of practical local fieldwork activities and investigative field visits becoming part of geography teaching internationally (Page *et al*., 2001). Teachers were gleaning learning materials in the form of geographic information from radio, television and newspaper to create learning opportunities above and beyond the prescribed textbooks[2]. Enquiry-based geography spurred the use of Information Technology (IT) in the geography classroom (Hassell, 1996; Holmes, 1996; Sheppard, 1995; Warner, 1994) where it was used for gathering, storing, analysing and presenting findings. While maps and map skills were presumably part of the new wave of educational research, little specific reference to spatial competence has been found during this period. In the last decade of the old millennium, research into map skills was subsumed into research into other aspects of geography teaching such as project work and enquiry-based learning with map skills often taken as a given, maps themselves seen as sources of location information or part of the presentation of findings.

In the last decade of the old and first decade of the new millennium, IT has been enhanced by the rapid expansion of communication technologies including access to the internet and the World Wide Web. IT grew into ICT. Hassell's (2002: 158) strongest case for including ICT in Geography is that learners '...deserve to have a geographical education which reflects the world in which they live'. So pervasive has ICT become in many countries that the Geographical Association (GA) and the National Council

[2] With the recent introduction of OBE, as described in Section 2.6, this is the point that geography teaching has just reached now in South Africa, more than 40 years later.

for Education Technology (NCET) in Britain consider it an entitlement for learners at both primary and secondary schools (NCET and GA, 1994), where ICT should be used to:

- enhance their skills of geographical enquiry
- gain access to a wide range of geographical knowledge and information sources
- deepen their understanding of environmental and spatial relationships
- experience alternative images of people , place and environment; and
- consider the wider impact of IT on people, place and environment

While ICT has the potential to increase understanding of the world, much rests on teaching strategies that encourage learner autonomy in the enquiry-based learning environment (Naisch *et al.*, 2002) so that there is a balance between teacher-directed work and independent enquiry by the learners.

2.5.3 From ICT to GIS

While investigation into map skills has seemingly been eschewed, as mentioned in Chapter One (1.1.2), research focusing on GIS in education abounds. GIS fervour has begun to dominate the spatial competence research arena. Green (2001b) reviewed the early efforts by various institutions, both state and commercial, to create an awareness of GIS and later to introduce teaching materials despite the fact that '...GIS technology has frequently been perceived to be very new, very technical and very demanding in terms of the IT learning curve required' (Green, 2001a, xviii). Page *et al.* reviewed the past, present and future of geographical information in UK schools and sketched the setting in which IT and GIS grew in popularity. They describe the presence in all geography classrooms of '...world and British Isles wall maps on linen, a world atlas and, (of course)[3] Ordnance Survey map extracts for map interpretation and national grid referencing exercises' (Page *et al.*, 2001: 26).

In his broad view of a globalised perspective on geographical education, Gerber (2006) stresses the need to go beyond the What? and Where? questions to the Why? How? and So What? questions and urges that '...the teaching of geography should reinstate explanation and critique, along with description, as its key cognitive processes' and that '...methods and techniques for maximising Primary and Secondary data in geographical education should be popularised across the international geographical education community so that fieldwork is maximised in the teaching and learning of geography and the informational power of the internet can be maximised across both developed and

[3] In many under-resourced schools in South Africa, as discussed in Chapter 6, this might be stated as 'no maps on the walls (of course)'!

developing regions of our world' (Gerber, 2006: 20). Fieldwork has long been recognised as a means to teach about the world. Using the power of new spatial information technology, all the advantages of enquiry-based, action learning (Prince, 2004) can be combined with data collection, analysis and presentation to enhance spatial comprehension by bringing the WORLD, the MAP, and how the world is understood in the MIND closer together (Figure 2.1).

GIS alone cannot solve spatial learning problems, the emphasis on effective fieldwork was stressed by Maguire (2006) in describing how a school based GIS project, conducted with broad community and local council support, lead to action that reversed the eutrophication of a local river mouth rendering the water clean enough to be used for swimming once again. This inclusive approach was recommended by Béneker *et al.* (2006) who found that *synergy*, *joint effort* and *recognition* are among the most important success factors for innovation (such as the use of GIS) to take hold in geography education. By synergy they meant that an innovation tends to be more successful if it can serve several goals at the same time, joint effort is understood as the degree to which the geographical community as a whole (academic geographers, teacher educators, teachers) supports the innovation, and recognition '...is the degree to which especially teachers recognise and accept the innovation as really important and as an enrichment of established practices' (Béneker *et al.*, 2006: 68). Andersland, working in Norway, also stresses the importance of teacher commitment indicating that most schools in that country have sufficient computer infrastructure, '...targeting the teacher is the key in the further implementation of GIS in geography education (Andersland, 2006: 42).

2.5.4 Creating GIS awareness among geography teachers

Following the rapid commercial development of GIS in the 1980's, the next decade saw the promotion of GIS at school level. The UK and USA offices of Environmental Systems Research Institute (ESRI), a commercial institution with clearly vested interests, led the way with the promotion of GIS Awareness Weeks in countries where their software was gaining ground in commercial and administrative applications. By the end of the decade and, with the expansion of the internet, GIS technology was moving from the confines of the academic community and into businesses, homes and schools in developed nations (Green, 2001c). ESRI created the ESRI Schools Prize in both UK and USA to promote the use of GIS and circulated *ArcSchool Reader* (Fitzpatrick, 1993) which provides resources and contact details for interested learners and teachers. In Canada, the Ontario Association for Geographic and Environmental Education's efforts to heighten GIS awareness included carrying information in their periodical *The Monograph* such as the advertisement of workshops and vendor products (Sharpe and Best, 2001) as well as articles promoting GIS as a pedagogical imperative (e.g. Gartrell, 1996; Robinson and Thornton, 1995 and Oliver, 1992, 1993 and 1994).

Starting in 1991, the monthly trade magazine *Mapping Awareness and GIS in Europe*, which carried a regular column on GIS in Education, was circulated to schools at a reduced rate (Green, 1991). Articles started appearing in *Teaching Geography* the journal of the Geographical Association (e.g. Freeman *et al.*, 1993 and 1994). The Geographical Association appointed a Working Group on GIS in School Education and the chairman developed a school curriculum on the subject (Coggins, 1990). The Association for Geographic Information appointed a Committee for Information and Education whose members had a strong interest in promoting GIS education in schools (Rhind, 1993a and 1993b).

Although acknowledging that, ultimately, IT facilities are required to conduct advanced investigations using GIS, Green (2001b) offers practical suggestions for introducing GIS concepts before IT facilities are required. He recommends using the transparent overlay technique to teach the basic concept of layering before introducing learners to GIS software. He describes the use of shaded grid squares on graph paper to illustrate rasterisation (using illustrations by Maguire, 1989) and explains the use of weighted map squares to conduct an environmental quality assessment based on work by Smith (1974). He suggests using pupil data to create a GIS-like file structure, based on records and fields and describes how to use the GIS concepts of point, line and polygon as well as vectors to draw a simple map of a learner's favourite room. He stresses that there is '...a need to develop a progression in manual GIS throughout school education to provide for a sound knowledge of the principles of GIS as a vital prerequisite for computer-based GIS' (Green, 2001b, 55).

Going one step further than 'manual' GIS, Campbell's spreadsheet activities (1989, 1990) require IT that is readily available and can be used to introduce elements of GIS (data input, storage, querying and mapping) without GIS software. Even when GIS software is available, Coggins (1990) indicates that the prior knowledge required before GIS education even begins includes basic map skills, basic numeracy, fieldwork and data collection and recording. While some fear the demise of basic map skills, as Coggins (1990) points out, basic map skills need not be compromised but rather they should be enhanced by the introduction of GIS into Geography.

2.5.5 Growth of GIS in education

The rapid changes brought about by GIS technology have the potential to change map use from a passive viewing activity to an interactive spatial learning experience. 'GIS represents a new generation of 'supermaps' that lie at the heart of all modern spatial decision making, whether it's locating a new store, planning public utilities or managing the environment' (Wiegand, 2006b: 8). Together with the global positioning system (GPS) used to pinpoint location, exciting possibilities now exist for displaying and manipulating local maps and maps of other areas in ways that will stimulate learners to explore their own environment and to investigate issues of both local and general concern.

Materials available for teaching with and about GIS at schools at the start of the millennium were reviewed by Green (2001a) and are summarised in Appendix 2.1. The focus ranges from local studies of a greenbelt (Walker, 2001) and coastal zone (Brown, 2001) to the ozone hole (NCGIA, 1993a and 1993b). Some projects stressed the acquisition of input data from GPS and fieldwork (Price and Heywood, 1994) or remote sensing (Biilmann, 2001) and others on GIS output such as map production (AUME, 1990). The importance of teacher training was stressed (Palladino and Goodchild, 1993; Cadoux-Hudson and Heywood, 1993; Palladino and Zuyle, 1996) as was the support of regional services (Smith, 1994; Gill and Roberts, 1998) and national mapping organisations (Ordnance Survey, 1999; Rhind, 1993a and 1993b, Galloway, 1997) in supplying appropriate digital data and other assistance. Adaptation of commercially available GIS software for school education purposes was highlighted (IDRISI 1996, 1998; Green, 1991, 1992 and 2001a; Chaloner, 1992).

When tasked with the responsibility for investigating spatial thinking and how it might be improved in American schools, the National Research Council (NRC) first identified the characteristics of someone who could be described as spatially literate; they would be proficient in '...spatial knowledge, spatial ways of thinking and acting, and spatial capabilities' (NRC, 2006: 18) and they would be able to match the norms for what should be known about space, representation and reasoning. After examining the use of spatial thinking in various areas of interest including science, astronomy, geosciences and geography the committee concluded that successful problem solving requires an ability to think spatially, that there are many ways to do so and that training in spatial thinking is related to work-place relevant skills. They go on to stress the importance of Mathematics and Science (but with applications in Geography through the use of maps) as the school subjects that are most important in developing spatial thinking. A South African investigation confirmed the value of Mathematics in enhancing spatial skills and is reported in Chapter Four.

Box 2.2
GIS and good citizenship

'To be a positive force in society, to make well-considered decisions, to be a resource with the potential to improve the quality of life – people need to be comfortable with exploring and integrating information, seeking relationships, thinking critically, acknowledging differences, and finding common ground. Using GIS, these essential skills can be developed in schools, in all subject matters, by students young and old, and with all degrees of innate ability.'

(Fitzpatrick and Maguire, 2001, 66)

In promoting GIS, Fitzpatrick and Maguire (2001) stress its value in citizenship education (see Box 2.2). They indicate that more important than the entire toolkit provided by GIS software is '...a disposition for exploration and a capacity to think geographically' (2001: 64). Practical examples of good citizenship projects are outlined in the ESRI publication by English and Feaster (2003). While taking learners (and their teachers) step by step through the intricacies of using ArcView® a range of projects are described with explanatory text and exercises following the geographic enquiry route. The eight projects include: making a city visitors map, reducing crime by increasing police patrols, fighting a weed infestation, monitoring the quality of a local river, identifying pollution sources, planning a school bus route, protecting a community forest and devising a wildlife area management plan. Unfortunately, although in both America and Britain much effort has been expended to introduce GIS into schools, Newell (1997) lamented that general awareness of GIS was still lacking in schools towards the end of the last decade and in the current one, Baker and Bednarz (2003) and Bednarz and Bednarz (2008) still report that uptake has been relatively slow.

2.5.6 Concerns about using GIS in education

While earlier research into teaching spatial skills tended to emphasise the use of large scale local spatial information to promote comprehension of maps, some early GIS materials and the investigations reporting their introduction to schools focussed on small scale, global data sets (Fitzpatrick, 1993). The early popularity of GIS amongst some educational institutions was based on its novelty value and assumed potential for teaching rather than on sound didactic principles (Biilmann, 1995). Unless used effectively to stimulate high level enquiry, Biilmann (2001) suggests that introducing GIS is '...normally a mere reinvention of atlas use or map reading, supported by information technology'. Fitzpatrick of ESRI, quoted in Alibrandi and Baker (2008: 17), accuses teachers who have adopted a 'step-by-step lesson leading to a pre-determined result' approach to GIS in education (rather than using the full range of GIS application tools to investigate pressing local issues) of '...using a Ferrari for commuter traffic'.

Although the availability of all forms of information technology grows exponentially, Page *et al.* (2001) warn there is also a downside (see Box 2.3) especially in economically divided societies. Using the conventional geography textbook as a source of information, teachers were safeguarded by stringent screening of publications before these were recommended for use in classrooms. Now quality control lies in their hands with little assistance from the industry because '...existing publishers have little interest in being rendered bankrupt by the supplanting of their books by a set of nerdish teachers surfing on the internet!' (Page *et al.*, 2001: 32).

Box 2.3
Downside of access to IT

'Not all information technology makes for good geographic information:

- the social consequences of a technology-push approach are often harmful and can be dehumanising
- some of the information is positively misleading, particularly since quality control for much of it is wholly absent or undefined
- filtering, retrieval and analysis of information is often much more difficult to make work satisfactorily than the enthusiasts acknowledge
- it imposes new costs (and stresses) on those in education
- it creates a culture of secondary data analysts who believe that all problems can be resolved by tapping at a keyboard
- it fosters laziness and lack of analysis in that students often simply 'cut and paste' vast amounts of material from a CD-Rom into their projects'.

(Page *et al.*, 2001, 30)

Two aspects of cost will inevitably influence the uptake of IT in South African geography classrooms – inequity of access and increasing financial burden over time. Even in the UK, Page *et al.* (2001) caution that only well resourced grant-maintained and major public schools may be able to afford the necessary hardware and software to make full use of IT (including GIS) in Geography. As long as unrestrained commercial interests are responsible for provision of hardware, software, data and training directly to schools, often based on costly annual licensing fees, costs may rise because these enterprises need to generate legitimate profits in order to stay in business. By harnessing the interests of institutions of state or special interest groups, economies of scale can bring costs down. Towards this end, in South Africa all digital spatial data currently under the authority of the national mapping organisation is provided free of charge to all users (www.sli.gov.za).

The factors that promote and impede the use of information communication technology (ICT) in schools have been investigated in Namibia. The findings of Matengu (2006) may have relevance for the likelihood of adoption of GIS in South African schools. He found that apart from changing political agendas related to development, a perceived need for technology by education officials was an important promotional factor. To counter this, the impeding factors included: inequalities between core and peripheral areas, lack of infrastructure, inadequately devised adoption strategies and lack of vision and guidance from policy makers. Lundall and Howell (2000) cited the following as factors preventing widespread computer use in South African education: insufficient funds, too few computers, lack of computer literacy among teachers, lack of computer-trained subject teachers and the absence of a computer skills curriculum. Lack of awareness of the requirements for using GIS in Geography is suggested by the paucity of information on GIS in their guide to managing ICT for South African school principals (Bialobrzeska and Cohen, 2005). The situation is not unique to African countries. It is reported that low levels of adoption of GIS in American schools can be attributed to limited access to hardware and software in schools, intimidating software, insufficient time available for learning to use the software and low levels of technology training for teachers (NRC, 2006).

An ambitious GIS in Education project was launched in Rwanda in 2008 (Forster *et al.*, 2007). In a collaborative effort between the Centre for GIS and Remote Sensing of the National University of Rwanda (CGIS-NUR), Kigali Institute of Education, Rwandan Ministry of Education and using licenses donated by Jack Dangermond of ESRI, trained teachers at ten pilot senior secondary schools started using GIS in their teaching and also trained teachers from three selected surrounding schools. The roll-out programme will repeat the 'snowball effect' with each newly trained teacher training three more each year. This forms part of Rwanda's 2020 vision to become the Singapore of Africa by promoting rapid advancement of ICT (Majtenyi, 2008). The dissemination is based on Telecentres which function as internet access points as well as training and support centres for local community development projects. The initial progress of this project, including the first ESRI Summer Camp in Africa was reported recently (CGIS-NUR, 2009) and further developments will be watched with great interest.

There are clearly two camps on the GIS in Education battlefield and the lines are not drawn strictly between technologically advanced first world and less advanced third world teams. Green suggests that, as software and hardware become increasingly user-friendly with better manuals and the fact that children readily adapt to a computer environment, GIS can be grasped by any geography teacher

(Green, 2001c). While this may be true in a well resourced school setting, those teachers who are less computer literate or for whom there is no access to computers, GIS may not be an option unless there is a concerted effort to assist them. Even in a developed world setting, Kerski (2003) reports that fewer than 8 % of American High Schools had purchased GIS software, only half the educators at those schools were using it and, of those, only 20 % used GIS in more than one lesson with more than one class. The Rwandan GIS in schools initiative (CGIS-NUR, 2009) is a model that serves to inspire hope for GIS in a developing or third world setting. Support from the highest levels of state is evidenced and may be partly responsible for the success to date.

Once learners can read a topographic map with understanding and analyse the spatial information presented on the map with confidence, they can be guided towards map interpretation. This advanced level of capability requires '...high-end or critical and creative thinking (that) extends beyond a natural processing of the world into the realm of deliberative thinking acts aimed at solving problems, making decisions and forming conclusions' (Ritchhart and Perkins, 2005: 776). Because GIS offers the opportunity to present more than one kind of data for the same location and makes it possible to link it to multiple layers of background data, the technology can be used to facilitate this higher order thinking. However, moving directly into GIS without establishing effective map comprehension and without first teaching the purpose and process of a range of basic map analysis tasks is likely to prove difficult, especially in a teaching environment where the teachers themselves have limited IT skills. Without a well established geographic concept framework for basic map comprehension, learners are likely to enjoy the novelty of the GIS analysis tools but will probably use them without understanding their purpose. Somewhat like teaching a range of thinking strategies without cultivating a sensitivity to occasions when thinking might be required or without motivating learners to invest the effort required to think through a decision or to plan a course of action (Ritchhart and Perkins, 2005).

After examining the reasons why the potential of geospatial technologies (GST) including GIS, for enhancing spatial learning were not being met in many countries, Bednarz and Bednarz (2008) developed and instituted the Advancing Geospatial Skills in Science and Social Science (AGSSS) programme. They identified the most significant barriers to diffusion of GST as (i) teachers' lack of understanding of the cognitive skills underlying the application of these technologies and (ii) their failure to understand the importance of spatial thinking. By addressing teachers' need for knowledge in four specific areas (content, pedagogy, pedagogy of the content and technology of the content pedagogy), preliminary findings indicate that the programme was successful in recognising: that educational change takes time even with considerable support, that some knowledge aspects are assimilated quicker than others (e.g. appropriate instructional strategies were developed to control unruly learners before full understanding was gained of the technology of the content pedagogy) and that spatial vocabulary and concept understanding are key to spatial thinking. Investigating the barriers to widespread GIS uptake in schools, Bunch *et al.* (2008) propose that the problem may be better addressed if it were tackled within its own body of research identified as Instructional Geographic Information Science (*InGIScience*), drawing on the disciplines of Geography, Psychology and Education.

2.6 CAN SOUTH AFRICA'S NEW CURRICULUM ENHANCE SPATIAL COMPETENCE?

2.6.1 Geography in the General Education and Training (GET) and Further Education and Training (FET) bands

The Revised National Curriculum Statement[4] (RNCS) for Grades R-9 makes provision for the General Education and Training Certificate (GETC) which acknowledges competence in eight Learning Areas: Languages (home and one other), Mathematics, Natural Sciences, Social Sciences, Arts and Culture, Life Orientation, Economic and Management Sciences and Technology (DoE, 2002a). The certificate is a pre-requisite for entry into the Further Education and Training (FET) band, allowing access to either upper secondary education or training in vocational schools or various training institutions.

Prior to the introduction of the new curriculum, Geography was an optional subject, not offered at all high schools and at those where it was offered, it was one of many electives from which learners could make a selection. When the National Curriculum Statement (NCS) for GET was first introduced (Ministry of Education, 1997), there were serious concerns about Geography losing ground in the Human and Social Sciences Learning Area (Van Harmelen, 1999). The Learning Area was revisited and redefined and now the Revised National Curriculum Statement (RNCS) for GET recognises the

[4] The original NCS for GET (C2005) was followed until the RNCS was implemented from Grade 7 in 2006 followed by Grade 8 and Grade 9 in 2007. The NCS for Grades 10 - 12 in the FET band was introduced concurrently starting in Grade 10 in 2006, Grade 11 in 2007 and in Grade 12 in 2008. The Further Education and Training Certificate (FETC) will be awarded to successful examination candidates in the FET Colleges. Learners in Grade 12 at all schools throughout South Africa wrote the National Senior Certificate (NSC) examinations in 2008 (DoE, 2005). This was the first cohort of school leavers to have completed the 12 year OBE programme that was introduced along with the NQF by the SAQA Act (No. 58 of 1995).

uniqueness of Geography and divides teaching time equally between History and Geography as individual subject components of the revised Social Sciences Learning Area (DoE, 2002a). Although not a full school subject, a major advantage is that Geography (as part of Social Sciences) is now compulsory for all learners to Grade 9, generally considered equal to the last year of junior secondary school. If used effectively, this opportunity could lead to improved spatial competence for all those who leave school after Grade 9 with a GETC or equivalent qualification. (This improvement will depend heavily on teacher training in teaching map use and on provision of adequate maps and other teaching resources.)

Because this investigation focuses on the senior secondary education phase, only the policy documents relevant to the FET were closely scrutinised. The Further Education and Training Certificate (FETC) is available to both adult and college based learners after three years of study beyond General Education and Training (see Table 1.2 in the previous chapter). Successful school based-learners earn the National Senior Certificate (NSC) if they attain passing scores in the examination of six subjects: two languages and Mathematics are compulsory and the other three subjects may be selected from a wide range of options, one of which is Geography.

2.6.2 An attempt to identify spatial competence outcomes at FET level for school leavers

The various policy documents for Geography, released by the Department of Education between 2002 and 2008, were eagerly anticipated. They were evaluated to test the hypothesis that they would make a positive contribution towards improving spatial competence in South Africa. Four assumptions relate to this hypothesis:

(i) the place of map skills in Geography would be assured,

(ii) a clear definition of spatial competence would be included,

(iii) there would be a hierarchy for developing spatial skills sequentially over the three FET Grades (10, 11 and 12), and

(iv) provision would be made for the use of GIS to enhance spatial competence.

Assumptions (ii) and (iii) have specific relevance to the development of a self-instruction programme for improving map analysis skills. The document names are italicised in the following with the relevant information from each one listed.

- *National Curriculum Statement (NCS) Grades 10-12, Geography* (DoE, 2003)

The National Curriculum Statement (NCS) is the official, legislated document regarding what is to be taught in schools. In the new OBE curriculum a subject is no longer defined by a specific body of academic knowledge; subject boundaries are less rigid with knowledge integrating theory, skills and values (DoE, 2003). However, a broad outline of the content to be covered is provided with content divided into five sections for each Grade (Table 2.1). Significantly, geographical skills and techniques are listed first each year.

Table 2.1 Content sections for FET Geography

Grade 10	**Grade 11**	**Grade 12**
A. Geographical Skills and Techniques B. Atmosphere: Weather and Climate C. The Structure and Changing Land forms of the Earth D. People and Places: Population E. People and their Organisations	A. Geographical Skills and Techniques B. The Significance of water masses C. Ecosystems (biotic and abiotic components) D. Development and sustainability E. People and their needs	A. Geographical Skills and Techniques B Climate and weather C. Fluvial processes and landforms D. People and Places: rural and urban settlement E. People and their needs

(DoE, 2003: summarised from pages 25 – 32)

It is suggested in the policy document that subjects are more broadly defined by their Learning Outcomes (LO's), which should be flexible enough to include new and diverse knowledge, including local inputs (see Box 2.4). It must be noted that while the learning contents for each year of the FET band differ (Table 2.1 above), the generic and rather vague Learning Outcomes for the FET band remain the same for Grades 10, 11 and 12.

Box 2.4
FET Learning Outcomes for Geography

'LEARNING OUTCOME 1: GEOGRAPHICAL SKILLS AND TECHNIQUES
The learner is able to demonstrate a range of geographical skills and techniques.
LEARNING OUTCOME 2: KNOWLEDGE AND UNDERSTANDING
The learner is able to demonstrate knowledge and understanding of processes and spatial patterns dealing with interactions between humans, and between humans and the environment in space and time.
LEARNING OUTCOME 3: APPLICATION
The learner is able to apply geographical skills and knowledge to phenomena, human and environmental issues and challenges, recognise values and attitudes and to demonstrate the ability to recommend possible solutions and strategies' .

(DoE, 2003, 14-16).

The NCS proposes that the geography learning content in each year should be used to develop practical, fundamental and application competencies (Learning Outcomes 1, 2 and 3). Spatial competence falls into the domain of practical competence. The search through the *NCS for Geography* looking for spatial competence outcomes revealed the contents of Table 2.2 where the general competencies expected of a Grade 12 learner taking Geography are listed. (To focus attention on aspects of spatial competence, key words in the table are highlighted: map terms, aerial photographs, imagery and the term - spatial.)

Table 2.2 General competencies expected of a Grade 12 learner of Geography (at the end of the FET band)

Skill	Acquire geographical information	Organise geographical information	Analyse geographical information
Literacy	Reading primary and secondary documents	Compiling research plans. Reporting and writing essays. Documenting data	Content analysis Critical reviews
Communication numeracy	Listening skills Sampling	Presentation skills Using descriptive statistics, conversions and indices	Seminar and debating skills Applying analytical statistics
Geographical numeracy	Doing measurements on maps and imagery Spatial sampling	Using digital mapping and map projections Applying cartographic principles	Applying GIS procedures and spatial statistics
Graphicacy	Interpreting maps, graphs, aerial photos, remotely sensed imagery, photos and works of art	Drawing maps Constructing graphs Converting imagery	Using map statistics Making inferences from maps, graphs, photos
Field methods	Interviewing, observing, completing questionnaires, doing measurements, e.g. Global positioning systems (GPS), making notes, taking photos, drawing maps and making sketches.	Classifying and summarising data	Making inferences from field observations

(DoE, 2003: 13)

No reference is made to *spatial competence* but the term *geographical numeracy* is introduced covering some map related activities (Table 2.2). More map skills are itemised under the heading *graphicacy* while there, and under *field methods*, map drawing appears. Although there is much emphasis on the importance of map skills, the terminology is inconsistent and there is no clear progression of skills indicated. This lack of progression has also been noted in other areas of the NCS for Geography by Beets and Le Grange (2005).

- *Learning Programme Guidelines (LPG) for Geography* (DoE, 2008a)

There is little guidance in the NCS offered to teachers about how they should organise the content and LO's into a programme for the year. Geography school textbook authors tasked with preparing learning and support materials for teachers and learners were left to interpret the brief outline as best they could (e.g. Beets, *et. al*., 2005b, 2006b, 2007b). A draft of the Learning Programme Guidelines was issued for comment prior to the release of the final document (DoE, 2008a). In the draft document, terminology was introduced that was different to that in the NCS which necessitated the rewriting of sections of the Grade 10 textbook (e.g. Beets, *et al*., 2008). The end point of a Learning Programme is to attain the Learning Outcomes that have been specified. The first Learning Outcome, referred to as LO1, is of relevance and is elaborated as follows: 'This Learning Outcome is achieved when learners are able to demonstrate the competence to ask questions, acquire, organise and analyse information, and make judgements based on the information gathered (enquiry skills). This includes competence in map use and map skills (spatial skills and techniques), and the manipulation of (electronic) geographical databases' (DoE, 2003: 14), the details laid out in Table 2.3.

Table 2.3 Elaboration of learning content for Geographical Skills and Techniques for the FET band

Grade 10	**Grade 11**	**Grade 12**
Map use and map skills: these include reading and analysis of maps, orthophoto maps, oblique and vertical aerial photographs and graphical data, executing techniques, for example • map orientation (map position, types of grid reference); • different types of scales used on different maps and photos; • direction and true bearing; • map calculations (distance, area, gradient, vertical exaggeration); • drawing cross-sections and determining intervisibility; • map analysis and interpretation	Map use and map skills: includes reading and analysis of maps, orthophoto maps, aerial photographs and graphical data, executing different techniques, for example: • consolidation and more advanced application of map skills and techniques done in Grade 10 on topographical maps aerial photos and orthophoto maps; • reading, analysis and interpretation of 1:50 000 topographical maps and orthophotos, integrating concepts done in content section	Map use and map skills: includes reading and analysis of maps, orthophoto maps, aerial photographs and graphical data, executing different techniques, for example: • consolidation and more advanced application of map skills and techniques done in Grade 10 and Grade 11 on topographical maps aerial photos and orthophoto maps; • reading, analysis and interpretation of 1:50 000 topographical maps and orthophotos, integrating concepts done in content section
Map projections: Lambert	Map Projections: Mercator	Map Projections: Gauss Conformal, Universal Transverse Mercator
Fieldwork: • using local maps/photos; • recording geographical information in the local area	Fieldwork: • using local maps/photos; • recording geographical information in the local area	Fieldwork: • using local maps/photos; • recording geographical information in the local area
Geographical Information Systems (GIS): • general concepts (e.g. systems, information systems, GIS, remote sensing) • geographical concepts (e.g. spatial objects, lines, points, nodes, scales [small versus large] resolution [spectral and spatial])	Functional elements of a GIS including: • data acquisition; • satellite remote sensing as a digital data source; • pre-processing; • data processing	Functional elements of a GIS including: • data management; • data manipulation and analysis, and spatial analysis; • product generation; • application

(DoE, 2003: 34 and 35)   Repetition

In Table 2.3 the relevant contents of the sections on Geographical Skills and Techniques are presented for each grade. This is preceded in the *NCS for Geography* by the instruction for each grade to '...familiarise and empower learners to use atlases on various themes as a rich source of spatially and non-spatially referenced data and information' (DoE, 2003: 34 and 35). Attention is drawn to the list of map related activities in Table 2.3 for Grade 10 (the beginning of the FET phase). The terminology in the contents list is confusing. There is no differentiation between skills and techniques. For example, analysis of maps appears at the top of the content list under the title *Map use and map skills*; the last item on a list of *techniques to be executed* is map analysis and interpretation. There is neither an attempt to specify a progression of techniques for Grade 11 and 12 nor to differentiate the skill levels at which competence should be demonstrated at the higher grades. The Grade 10 list is summarised and repeated for each succeeding grade with the injunction to consolidate what has been done the year before with more advanced application of map skills and techniques. Although topographic map study is only mentioned specifically from Grade 11, much of the Grade 10 content, starting with orientation of maps is traditionally taught using a topographic map. Having found little to guide the development of a self-instruction programme for map analysis in the Learning Programme Guidelines, attention turned to the Subject Assessment Guidelines which should offer teachers an indication of how to evaluate the outcome of the learning programme they are tasked to administer.

- *Subject Assessment Guidelines (SAG) for Geography* (DoE, 2008b)

The five Assessment Standards (AS's) for LO1, Geographical Skills and Techniques, are listed in Table 2.4 with key words again highlighted. In this case there are only two specific references to maps and no mention is made of the map skills that are to be assessed.

Table 2.4 Assessment standards for Geographical Skills and Techniques

LO1	**Geographical Skills and Techniques - Practical Competence** Learners can claim this competence when they are able to				
	AS1.1	**AS1.2**	**AS1.3**	**AS1.4**	**AS1.5**
Grade 10	Identify issues and formulate questions for an investigation	Acquire information from fieldwork and a variety of other sources	Organise information graphically, pictorially and diagrammatically	Analyse information obtained from a variety of sources	Report findings on oral and/or written form
Grade 11	Plan and structure a project or enquiry process	Acquire a variety of information from relevant primary and secondary sources which include fieldwork	Classify the acquired information according to different categories	Analyse information obtained from a variety of sources - including fieldwork data, 1:50 000 topographical maps, orthophoto maps and statistics	Report findings in written, oral and/or illustrative form
Grade 12	Plan a geographical research project of limited extent in a familiar context.	Integrate information from a variety of sources	Compare and contrast information from a variety of sources.	Analyse the acquired information in order to answer the initial question	Substantiate findings in written, oral or illustrative form

(DoE, 2003: 18 and 19)

In the Content Framework for Geography in the *SAG*, map skills are listed (once again) for Grade 10 with no evidence of a gradual progression from easy to more difficult spatial concepts and the whole list is repeated for Grade 11 and Grade 12 (DoE, 2008b). The example of a work schedule in the *LPG* for Grade 10 offers guidelines which should help teachers introduce the map skills by breaking the content list up over the first three school terms (DoE, 2008a) but the various skills are not introduced in the order listed in the *SAG*. The order of the skills does not appear to have been progressed conceptually (e.g. vertical exaggeration is listed before the topic of cross-sections is addressed). For Grade 10 the '...concept of contour lines, contour interval and altitude' is listed in the *SAG* (DoE, 2008a) but is not mentioned in the *LPG* (DoE, 2008b) although calculation of gradient is required. While topographic maps are listed as resources required for Grade 10 in the *LPG* (DoE, 2008b), they are not named specifically in the *SAG* (DoE, 2008a). However, topographic map study is specified under the Content Framework in Grade 11 and then again in Grade 12.

2.6.3 Discussion of the *NCS for Geography* and other curriculum documents

A search through the Learning Outcomes and Assessment Standards in the *NCS for Geography* (DoE, 2003) for the last three years of secondary school (FET) revealed little that could be used to identify a hierarchy of spatial competence outcomes for senior secondary school learners. Although the term 'sources' is used repeatedly, only two specific references to maps are made with no reference to other spatial information products. While teachers who have had adequate training and experience will no doubt have such sources, for new or inadequately trained teachers who have had little experience or exposure to maps, it is unlikely that they will have relevant sources or know how to access them. The two official documents long awaited by teachers for assistance with implementation of the *NCS for Geography*, the *LPG* (DoE, 2008a) and *SAG* (DoE, 2008b) appear to contradict each other on the topic of spatial competence and provide scant assistance in the development of a graduated programme of map analysis skills acquisition.

The Further Education and Training documents have been carefully scrutinised (without success) for a clear definition of spatial competence and a hierarchy for introducing map skills in a way that helps learners move from simple to more complicated tasks, gaining confidence as they progress (Alexander and Blanchard, 1985). While there is ample evidence that map use has been given a central place within Geography, and that maps are to be used to investigate real issues in local contexts that have impact on learners' lives, guidance on what map use techniques should be introduced when, and at what skill level, is not given.

Introduction of GIS into the new Geography curriculum is a brave step forward. Teachers will find that there is a far greater degree of progression of GIS concepts (see Table 2.3), compared with map use concepts, in the *SAG's* Content Framework for Geography (DoE, 2008b: 21 and 22). What is surprising is that, when it comes to the examples of Work Schedules across the three Grades in the *LPG* (DoE, 2008a: 35 - 45), only some of these concepts have been itemised in Grades 10 and 11 while none of the Grade 12 GIS Content appears in the Grade 12 Work Schedule.

2.6.4 Findings of policy document search for developing spatial competence guidelines

The hypothesis that the education policy documents can make a positive contribution towards improving spatial competence in South Africa is only partially proved. The first assumption that the place of map skills in Geography would be secured is valid. Unfortunately, the second assumption that a clear definition of spatial competence would be provided, and the third assumption, that there would be a hierarchy for developing sequential spatial skills over the three years in the FET band, were unfounded. Provision has been made, at policy level, for the use of GIS to enhance spatial competence. However, as will be discussed in Chapter Six, significant barriers to implementation need to be overcome.

Poor map use performance has long been a concern in South Africa and the extent of the problem was confirmed by the analysis of the practical examination scores for 2000 to 2007 in Chapter One (1.6). For the majority of the population this is largely due to discriminatory apartheid education policies. The New Curriculum Model for South African education and Geography's place in it, have been described here. While spatial competence is not listed specifically as a learning outcome for Geography at either GET or FET level, the emphasis on enquiry, on geographical skills and on environmental issues offers great scope for creating learning experiences that involve maps. What is implicit in the *NCS for Geography* (DoE, 2003) needs to be made explicit in order to realise the potential of the new curriculum for improving spatial competence.

2.6.5 Implementing GIS in South African geography classrooms

Implementation of the *NCS for Geography* at FET level introduced GIS to learners in Grade 10 in 2006, Grade 11 in 2007 and Grade 12 in 2008. Carolissen *et al.*, (2006) reported on teachers' perceptions of GIS and the challenges they face in the local province (Western Cape). Prior to implementation, a programme of curriculum advisor training was undertaken. In a pilot project involving 25 high schools, two different service providers (GIMS and Naperian GIS Technologies) both installed GIS software packages (ArcView® 3.3 and Geomatica respectively). After initial training by the service providers, the teachers at the 25 pilot schools were given three to four months to evaluate both software packages and recommend one of them for implementation throughout the province. Teachers perceived that the training was concentrated on mapping applications and not on the theory and principles underlying GIS as prescribed in the curriculum (Table 2.3). Despite the fact that teachers felt that their choice of software was ill-informed because they were still getting to know about GIS, the tender for installing ArcView® 3.3 in all high schools, offering Geography to Grade 12, in the Western Cape was awarded to GIMS (Rust and Kindler, 2008). No report, on the evaluation process followed by the teachers or curriculum advisors, has come to hand but the fact that ArcView® 3.3 had already been installed in two other provinces, Gauteng and Eastern Cape, may have influenced the decision (ostensibly in the interests of implementing a standardised curriculum).

Although reports on the implementation of GIS in the other provinces have not come to hand, investigations into computers in schools have. According to the findings of Lundall and Howell (2000), only about 10 % of the almost 28 000 schools in South Africa (both primary and high schools) had computers at the start of the millennium. Over time, the situation has improved to about 13 % with the majority of computer using schools in the Western Cape and Gauteng '... and it is no co-incidence that they are also the two wealthiest provinces ...' (Howie *et al.*, 2005: 109).

2.7 CONCLUSION

About 35 years ago, Stea and Blaut claimed that 'spatial learning has been neglected as much by educators as by psychologists engaged in the study of learning' (1973b: 233) and further that 'spatial cognition is of fundamental importance in the development process and its neglect by traditional theoretical and education systems in unfortunate' (1973b: 225). In 2006, the Geographical Sciences

Committee of the National Research Council under the chairmanship of Roger Downs acknowledged that 'spatial thinking is pervasive: it is vital across a wide range of domains of practical and scientific knowledge; yet it is underrecognized, undervalued, underappreciated, and therefore, underinstructed' (NRC, 2006: 14). In reviewing lessons learned from research in GIS education it was found that 'a common thread across several articles is a recognition of the need to help students better analyse the maps they produce – the need for explicit instruction in spatial analysis to promote student understanding of the meaning of the data that has been mapped' (Baker and Bednarz, 2003: 232).

In the diagrammatic representation of the elements of the spatial learning arena in Figure 2.1, the arrows represent strategies required to nudge the image in the MIND, the graphic display on the MAP and the understanding of the WORLD closer into alignment in order to enhance spatial competence. A review of the literature indicates that some early studies have identified mechanisms for bringing some of these elements together and, more recently, there is a need to engage pedagogy, psychology and geography education to jointly promote spatial competence (Bunch *et al.*, 2008).

CHAPTER 3
EVALUATION OF A SELF-INSTRUCTION METHOD FOR TOPOGRAPHIC MAP READING

'...first of all play, paint on the maps, draw in lines and points, but in a very playful fashion...
...the language should be of a sort that chimes, that is audible, and not just something for reading...'
Christaller, 1972:610

3.1 INTRODUCTION

The self-instruction method for analysing spatial information, the development of which is the proposed major outcome of this thesis, is an extension of *MapTrix* (Innes, 2000), an existing self-instruction programme designed by the author for reading the South African 1:50 000 topographic map (Figure 3.1).

Figure 3.1 Packaging of the *MapTrix* Kit

The research undertaken to develop the prototype of the learning programme for map reading spanned eight years from 1990 to 1998, publication took another two years (see Table 3.1). In this chapter, the research, development and classroom trial of *MapTrix* are only briefly outlined and events leading to its publication are described. The delivery of these learner support materials to schools, with the assistance of officials in the nine provincial education departments, is traced. The use of a postal questionnaire survey to evaluate *MapTrix* is described, the results of which reveal both teachers' and learners' attitudes towards *MapTrix*. The need for learner support materials revealed by the survey is discussed in greater depth in Chapter Six. While attitudes were positive overall, constructive criticism has influenced the development of the advanced self-instruction programme for analysing spatial information.

Table 3.1 Time line summarising the development of *MapTrix* (Innes, 2000)

1980 to 1992	The author's geography teaching experience from primary to tertiary levels highlighted learners' difficulties with maps evidenced by poor map use performance. This was particularly evident in schools discriminated against under the apartheid education system in South Africa. Two unsuccessful research proposals were formulated.
1993	Author appointed geography lecturer at a homeland university where evidence of poor map use skills again spurred research interest. Registration at Wits for an M.Ed by dissertation was approved under the preliminary title of - *Learning to read the South African topographic map: a self instruction approach.* Contact was established with an ex-geography teacher on the staff of the NMO who provided a list of 23 topographic map sheets using recently updated symbols and illustrating phenomena relative to geography teaching.
1994	New democratic government in South Africa ushered in radical education reform. Head of the NMO (the Chief Surveyor-General, at that time) approved the research project, donated map sheets and offered access to the organisation's library for further research. Extensive list of map symbol explanations prepared and approved by the NMO.
1995	Preparation of map reading exercises and attempts to fully explain map symbols, started in 1993, was continued. Extensive literature search was undertaken to identify principles for developing learner support materials for topographic map reading.
1996	Randomly developed map use exercises and symbol explanations were eventually organised into the structure of a pack of playing cards. Arranged to support a framework of 12 geography lessons (and pre-determined groups of symbols and words), the balance of the 52 map extracts were selected. Ten-question graded exercises were developed for each map extract and symbol explanations were allocated per work card. An attempt to have each symbol illustrated with a line drawing was unsuccessful.
1997	June: Appointed to the staff of the NMO to establish and co-ordinate MapAware, a national map awareness and map literacy campaign. July: Conducted a formative assessment of the completed components of the MapTrix prototype during a trial by newly appointed survey and cartography trainees at the NMO. September: Implemented the first step of the school-based thrust of the MapAware Project, the MapPack, providing five free local topographic maps to schools teaching Geography to Grade 12. October: Secured permission to use photographs commissioned for the MapAware Video to illustrate the symbol explanations for *MapTrix*. November: MapTrix prototype trialled at a local high school (and found to be effective).
1998	Research completed, M.Ed. awarded (Innes, 1998) for *Learning to read the 1:50 000 Topographic Map of South Africa: the development of a self-instruction method.*
1999	With approval of the NMO, private sector/public sector sponsorship for publication of *MapTrix* was sought. When cost of publication was investigated, the private sector partner withdrew.
2000	State funding by the Department of Land Affairs was approved and a tender awarded for the publication and distribution of *MapTrix Kits*. A teacher training video for implementing *MapTrix* was produced in collaboration with Edumedia. *MapTrix* was launched during celebrations marking the 80th anniversary of the NMO where the National Minister of Education accepted the donated Kits.
2001	200 Kits were won as prizes in a competition run in an educational newspaper, 1 800 Kits were presented to education authorities in 9 Provinces.

3.2 *MAPTRIX* DEVELOPMENT

3.2.1 Context within which *MapTrix* was developed

Self-instruction was investigated as a possible methodology for learning to read the 1:50 000 topographic map of South Africa (Innes, 1998). The research was undertaken with high school geography learners in mind, especially those at under-resourced schools facing a school-leaving map use examination, whose teachers were ill prepared to help them due to lack of training and resources. Aware of the plight of these learners and teachers, the author was guided in her search for a solution to the 'mapwork' problem by her research supervisor Professor John Earle. At the time, he was Head of Geography Education at the University of the Witwatersrand, Johannesburg (Wits). As the national examination moderator for the geography practical paper, he was also fully aware of the problem, evidenced as it was by poor examination performance. Management of the South African national mapping organisation (NMO) encouraged the research, the staff provided invaluable assistance and the organisation was later instrumental in securing finance for publishing *MapTrix* (Innes, 2000).[1]

The shared, self-instruction, loose-leaf work card format places a wide variety of topographic map extracts with a structured geography learning programme directly into learners' hands. Geography school textbooks (available at the time the research was being conducted) usually contained two or three topographic map exercises. A few specialised map use textbooks were available at the time (Nicholson and Morton, 1967 revised 1974; Liebenberg *et al.*, 1976; Liebenberg, 1986 revised 1992; Blackbeard, 1992; Burton and Pitt, 1993), which have recently been complemented by a new publication based on outcomes based education (OBE) guidelines to prepare learners for the National Senior Certificate (NSC) geography examination (Earle and Bowerman, 2007). No comparable self-instruction programme for learning to read the South Africa topographic map had previously existed.

The principles used to guide the development of the prototype self-instruction programme for map reading were distilled from a review of work in many research areas combined with personal findings while teaching, tutoring and lecturing map use and are presented in Box 3.1.

[1] Possible effects of vested interest are acknowledged in the evaluation of *MapTrix*. Although the author's research interest lay in evaluating the self-instruction method as a means to improve spatial competence, part of the author's line function as a staff member of the NMO was to evaluate the LTSM to assess its effectiveness in relation to the DLA's donation to the DoE. Because there are no comparable publications against which to evaluate *MapTrix*, great care was exercised in the design of the questionnaire to limit bias in the interpretation of the findings of the opinion survey.

Box 3.1
Guiding principles used for developing self-instruction materials for map reading. (MapTrix)

Reading theory:

(i) A conceptual reference framework must be developed to facilitate reading comprehension *i.e.* a map user must understand the Geography of the landscape to understand its representation on a topographic map (and must be able to use geographical terminology to read and answer questions).

(ii) Full comprehension of geographical information represented by each symbol and word on the map is the key to understanding maps.

Self-instruction methodology:

(i) Effective task analysis identifies an appropriate sequence for teaching skills.

(ii) Foundation skills (map reading) must be consolidated before advanced skills (analysis and interpretation) are taught.

(iii) Skills can only improve with repeated practice.

(iv) Immediate feedback reinforces learning.

Cartographic communication theory:

(i) The map user has equal responsibility with the mapmaker for creating cartographic meaning (concerted cognitive effort is required from both).

(ii) Teaching how maps are made does not produce proficient map users (just as teaching how rackets are manufactured does not produce good tennis players).

(iii) While improving the skills of proficient map users, teaching cartographic construction techniques (e.g. map projection) just confuses novice map users.

General education theory:

(i) Learning is constructed (or knowledge accumulated) through life experience; where this is limited (e.g. by poverty) provide carefully devised scaffolding.

(ii) Measurable target performance can only be identified from clearly specified learning outcomes.

Geography education research:

(i) To improve map skills use active learning (especially fieldwork) where possible, alternately provide vicarious experiences through film, pictures etc.

(ii) Incorporate map studies into all aspects of geography teaching.

(adapted from Innes, 1998)

3.2.2 Map reading programme structure

Table 3.2 Structure of the *MapTrix* learning programme

Main theme (and background colour)	Suit name and symbol	Sub-theme lesson	Playing cards numbers
Urban Settlement (Blue)	Clubs ♣	Industrial areas Small towns Large cities	Odd numbers Even numbers Picture cards
Rural settlement (Green)	Hearts ♥	Primary activities Commercial agriculture Subsistence farming	Odd numbers Even numbers Picture cards
Transport (Red)	Diamonds ♦	Railways Road networks Various transport types	Odd numbers Even numbers Picture cards
Landscape (Brown)	Spades ♠	Mountains Valleys Plains	Odd numbers Even numbers Picture cards

Because it was to focus on map reading, map symbols were identified as the key element in the learning programme. Close study of an initial selection of 23 map sheets revealed 93 significant named or symbolised features requiring explanation. A means was sought to combine these explanations into lessons and exercises so that learners would have to complete a minimum number of exercises in order to learn about a maximum number of symbols. Various groupings were attempted. By a process of trial and error, groups of symbols were linked to four broad geographic themes: urban settlement, rural settlement, transport and landscape. These categories, selected for the purpose of structuring the programme, may also support place learning by matching the tendency of learners to categorise the world (MacEachren, 2004). Sub-themes were then identified and map extracts sought to illustrate each of them. Text was written for each lesson, sub-lesson and symbol explanation to explain the geographic information on a topographic map especially the associated terminology. Table 3.2 illustrates the categories selected and shows how playing card symbols and numbers, as well as different coloured backgrounds, are used by learners to match work cards and answer cards for self-assessment.

Figure 3.2 The backs of a range of work cards showing lessons and illustrated map symbols

A3 format work cards (see example in Appendix 4.1) provide sufficient space for a map extract and exercise of ten graded questions on one side and the geography lesson and ten illustrated symbol explanations on the other (see Figure 3.2). The extent (52 work and answer cards) provides sufficient material for each member of a class of up to 40 for simultaneous self-study with 12 spare work cards that can be exchanged as learners complete one exercise and go on to the next. The Educators Guide and poster assist with programme implementation, monitoring and follow-up. The Learners Booklet (which can be photocopied onto an A3 page) guides the learner through the programme and is used to answer questions, record and graph progress. A 1:2 000 000 wall map of South Africa and an index to the 1:50 000 topographic map series assists teachers to take the first step of the programme which urges them to acquire and display the local topographic map sheet on the classroom wall.

It was through co-operation between the author and senior management of the NMO that funds were secured for publication. The project manager representing the publishers had shown prior interest in the research and took special care to accommodate all specifications. The author was allowed significant influence regarding the design and layout and enjoyed productive co-operation with the graphic designer.

3.2.3 Cartography used for *MapTrix*

The 1:50 000 topographic map is the base map of the South African national map series consisting of 1 916 sheets, each representing 15' latitude by 15' longitude. Each map extract of 5' x 5', used for a *MapTrix* work card, represents a significant geographical feature or theme and was selected because it included a predetermined group of map symbols. Descriptive location information was given for each map extract rather than a locator map. Red grid lines at half-minute intervals were superimposed on each map extract with letters used for the rows and numbers for the columns. This alphanumeric grid was indispensable for directing questions and locating answers.

Apart from the reference grid, the actual appearance of the topographic map was left unchanged. The selection of specific, 'uncluttered' extracts illustrating specific geography lessons was the only adaptation to meet learners' needs. Place names of the national map series must comply with the South African place names authority and were not, therefore, amended. Map extracts were selected from a range of areas so that mother-tongue speakers of the eleven official languages were likely to encounter at least some extracts with familiar sounding place names. Learners are guaranteed to encounter at least sixty different words and symbols most commonly used on the topographic map by selecting only one work card on each sub-theme according to the instructions. As more exercises are completed to improve proficiency, so more symbols are encountered. All symbols are listed at the back of the *MapTrix Educator's Guide* and referenced to each work card on which its illustrated explanation appears. The maps, lessons and exercises based on learning about the geography of places from their maps are integrated to form a relatively low cost cartographic education tool.

3.2.4 Classroom trials of the *MapTrix* prototype

During the classroom trial of the prototype *MapTrix Kit* the following hypothesis was tested: an intervention instrument, based on a self-instruction method, can be developed to measurably improve map reading. The mean difference between the pre- and post-test scores of participants in the trial was an improvement of 26,4 %. Time taken to complete the post-test improved by an average of 5 minutes over the pre-test. The learners who trialled the materials spoke a variety of home languages although their medium of instruction was always English. The performance of all language groups improved, from 28,8 % for home language English speakers to 23,5 % for those speaking Xhosa at home. There was little difference between the improved scores for males and females. There was no correlation between age and map reading performance in the test population (Innes, 1998).

While one classroom trial is an inconclusive evaluation of a novel learning approach, it served to highlight components needing more work and assisted in the compilation of the *MapTrix Educators Guide* making valuable contributions to the final text submitted for publication. It was also realised that, while learners effectively used the materials to teach themselves, the administration of the process had to be carefully explained and the assistance of the class teacher was indispensible to the process. An individual learner would probably be able to follow the instructions if working alone but to share the resource effectively, the teacher (or lecturer if used at tertiary level) has an important role to play. The materials must be distributed widely and evaluated in a range of classroom situations to assess whether the self-instruction methodology is effective in improving map use performance.

3.2.5 Product description

MapTrix: a self-instruction programme for learning to read the 1:50 000 Topographic Map of South Africa (Innes, 2000) was published by Juta and Company (Pty) Ltd in Cape Town, South Africa in fulfilment of Government Order number SM15/99LA, (placed when the company won tender SMP 8/1/1). Whereas copyright on all maps and colour illustrations is held by the Chief Directorate: Surveys and Mapping (CDSM), copyright on all text is held by the author. Of the state-subsidised first edition of 3 000 copies, 2 000 were donated to schools and 1 000 were sold at a subsidised price. No further impressions of the publication have been state subsidised. A second impression of 1 000 copies was published in 2002 by the same publisher, which was later bought out. In 2006 a third impression of approximately 500 copies was published by the new owners, Nasou Via Afrika through a subsidiary company, Smile Idem, which made unauthorised changes to the packaging and quality of the board used for the work cards. Negotiations are underway for an updated second edition and improved marketing.

Figure 3.3 Examples of the main components of the *MapTrix Kit*

The original format of publication was a large green and white cardboard box (see Figure 3.1) measuring 45 cm x 33 cm x 4.5 cm, containing the learning materials or *MapTrix Kit* (see Figure 3.3). These include 52 A3-size work cards, 52 playing/answer cards, a poster (84 cm x 60 cm), the *MapTrix Educator's Guide* (A5, 35 pages) and 10 Learners Booklets (A3 sheet, zigzag folds to 10 pages, can be photocopied). The first 2000 donated Kits each contained an extra 40 Learners Booklets.

Suggestions from the class teachers who assisted with the classroom trials included additional materials. These include a 104 cm x 77 cm wall map of South Africa at 1:2 000 000 published by the national mapping organisation (NMO), an index to the South African 1:50 000 topographic map sheets, an offer of five free local maps, an order form for the *MapTrix Video* (CDSM, 2000) and an information sheet on careers in cartography. The target users are novice topographic map readers especially high school geography learners in South Africa aged 13-19 years preparing for the General Education and Training (GET), Further Education and Training (FET) and National Senior Certificates.

3.3 THE *MAPTRIX VIDEO*

Concern was expressed that educators may need assistance in implementing the self-instruction programme, a significant departure from the textbook-based methodology commonly practiced in under-resourced schools. Edumedia, the educational media production unit of the Western Cape Education Department (www.edumedia.wcape.school.za), was commissioned by the NMO to produce a teacher training video. The story line is a dialogue between a staff member of the MapAware Project and a geography teacher wanting her learners to use their local topographic map sheet in an investigation of the pollution in a stream near their school (CDSM, 2000).

There are four sections, of which the first two can be shown in the classroom. First, various uses for topographic maps are discussed at the map sales desk of the NMO. Then the four geographic themes used to structure the learning programme (rural settlement, urban settlement, transport and landscape) are demonstrated from a vantage point on a hill slope in the Helderberg Nature Reserve (Western Cape) overlooking surrounding examples. In the second half, the components of the Kit are unpacked onto a table and the use of each item is explained. The scene then moves to a classroom where *MapTrix* is in use by a group of learners who follow the instructions for selecting work cards, reading the lessons and symbol explanations, doing the exercise, answering the questions and then marking, scoring and graphing the results of each one.

3.4 DISTRIBUTION OF DONATED *MAPTRIX KITS* AND *VIDEOS*

3.4.1 *MapTrix* presented to the Minister of Education

Figure 3.4 The Minister of Education holds a *MapTrix Kit* aloft, watched by the Chief Director of Surveys and Mapping (left) and the Deputy Minister of Land Affairs (as at October 2000)

In October 2000, the Chief Directorate: Surveys and Mapping celebrated their 80th Anniversary as the National Mapping Organisation serving South Africa. As part of the celebrations *MapTrix Kits* were presented to the Minister of Education, Kader Asmal, as a ‘gift to the nation’. Of the 3 000 *MapTrix Kits* that were published, 2 000 were donated and 1 000 made available for commercial distribution at a state-subsidised price. Presentation Kits were delivered just in time for the ceremony (Figure 3.4). In his response, Minister Asmal stressed the importance of helping all young South Africans to develop a sense of place.

3.4.2 *MapTrix Kits* given away as competition prizes

Full production of the first impression of 3 000 *MapTrix Kits* was completed by December 2000. In order to offer all schools an opportunity to benefit from the donation of free materials and not just under-resourced schools, 200 Kits were set aside as prizes to be won in a competition. This was carried in the January 2001 issue of *The Teacher* newspaper. Following an informative advertorial profiling the MapAware Project’s assistance to school Geography and explaining the background, publication and use of *MapTrix*, the competition involved filling in the answers to two questions on an entry form:

(1) Name the national mapping organisation of South Africa.

(2) Name the government department that sponsored the publication of MapTrix.

Table 3.3 Results of *The Teacher* Competition for 200 *MapTrix Kits*

Province	Total entries	Disqualified entries	Unsuccessful entries	Condoned winners	Outright winners	Total winning entries
Northern Cape	3	0	1	0	2	**2**
Free State	19	4	0	0	15	**15**
Gauteng	89	69	3	1	16	**17**
Mpumalanga	24	5	0	0	19	**19**
Limpopo	31	9	0	0	22	**22**
North West	35	6	4	1	24	**25**
Western Cape	281	249	3	4	25	**29**
KwaZulu-Natal	51	8	9	2	32	**34**
Eastern Cape	55	10	8	0	37	**37**
Totals	588	360	28	8	192	**200**

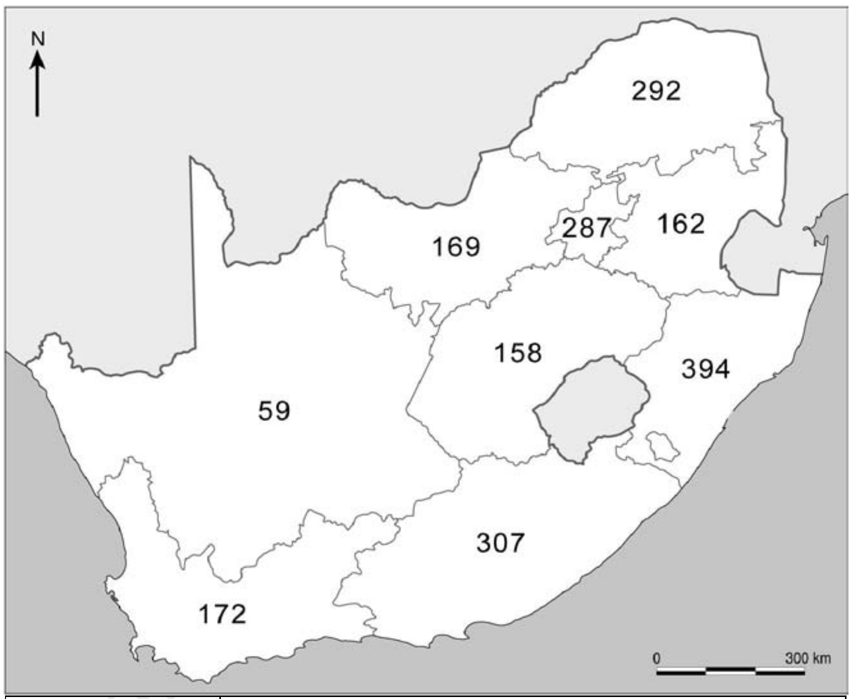
Disqualified = wrong answers or more than 10 entries per school
Unsuccessful = arrived after due date
Condoned = minor error

The Teacher is distributed to all schools throughout South Africa (estimated at the time to be approximately 27 000). As prizes were to be awarded to the school (not an individual) a maximum of ten entries per school were accepted. The response to the competition is summarised in Table 3.3. Winning schools were advised by the NMO and the publishers distributed the prizes by post.

3.4.3 Presentation of *MapTrix Kits* and *MapTrix Videos* to Provincial Education Departments

The 1 800 *MapTrix Kits* earmarked for under-resourced schools were divided up according to a breakdown of schools per province offering Geography to Grade 12, based on data provided by the Ministry of Education (Figure 3.5). Initially it was hoped that each Provincial Education Department would supply the names and addresses of their most needy schools and that the Kits would be posted to them. Red tape and lack of appropriate communication channels prevented this. Instead, to fast track the despatch of the learning materials, a road-show was organised during February and March 2001 and the author (who was a member of the MapAware staff at the time) visited a venue in each province to hand over the Kits.

Invitations to attend these hand-over ceremonies were extended to all geography education stakeholders in each province. On behalf of the Chief Director: Surveys and Mapping, letters of invitation were sent to each of the nine provincial Members of the Executive Councils (MEC's) responsible for Education as well as the managers or chief executive officers of the provincial education departments. Where possible, invitations were also issued directly to geography curriculum heads, subject advisors and examiners. All were asked to forward invitations to other stakeholders known to them and to local geography teachers. At each ceremony the MapAware Project's schools assistance programme was described. The *MapTrix Video* was shown and it was strongly recommended that all subject advisors (at least) be supplied with these for teacher training. At the end of each ceremony, presentation materials including maps of the local area, a history of surveying and mapping in South Africa (DLA, 2000), a *MapTrix Video* (CDSM, 2000) and the *MapTrix Kits* (Innes, 2000) allocated to that province were handed over to the most senior official in attendance. Figure 3.5 shows the total number of Kits made available at no cost to schools in each province.



Province name	*MapTrix Kits* distributed per province		
	Competition prizes	Departmental allocation	Total
Northern Cape	2	57	59
Free State	15	143	158
Mpumalanga	19	143	162
North West	25	144	169
Western Cape	29	143	172
Gauteng	17	270	287
Limpopo	22	270	292
Eastern Cape	37	270	307
KwaZulu-Natal	34	360	394
Totals	**200**	**1 800**	**2 000**

Figure 3.5 Total numbers of *MapTrix Kits* donated per province (both prize-winning schools and proportional allocation to each provincial education department)

In return for the donation of learning materials, education department officials were requested to (a) identify schools most in need and allocate *Kits* to them, (b) give teachers some training in the implementation of the programme using the *MapTrix Video* (c) arrange for *MapTrix Kits* to be delivered to the identified schools (d) supply the NMO with the names and postal addresses of all schools that received *MapTrix Kits*. It was explained that the school details were required in order to

- conduct a survey of the geography educators' and learners' opinions of the support material for topographic map reading and to
- consult and collaborate with teachers in the possible future development and trialling of companion Kits, for map analysis and interpretation.

3.5 MATERIALS AND METHODS FOR CONDUCTING THE *MAPTRIX* EVALUATION

3.5.1 Obtaining recipient school names and addresses

MapTrix Kits were distributed in bulk to a venue in each province during February and March 2001. The next step was to acquire the names and addresses of the schools that received the learning materials so that a questionnaire survey could be conducted to elicit educator's responses to the learning and teaching support materials (LTSM) and especially to the self-instruction method. It was initially hoped to conduct the survey by mid-year 2001.

While officials in some provinces were very diligent in allocating Kits, delivering them to schools and offering training, others were less so. By May 2001 Mpumalanga, Northern Cape and Western Cape had already allocated all the donated *MapTrix Kits* for training and for use in schools. In some cases distribution had also been completed. While other provinces had made some progress in allocating Kits, very few had supplied the addresses of the schools to which they had been allocated. Repeated attempts by letter, email and telephone were made to secure the school contact details from all provinces. Information trickled in very slowly. In some cases responsibility for allocation, training and distribution had been devolved to regional or district offices where the subject advisors had each used Kits for training. Some of these offices supplied school names only, others supplied names and telephone numbers but few gave addresses. The returns were assessed and in June 2001 a report was sent to the Minister of Education and to each provincial authority describing the response to date. A reply from the Minister's Office indicated that the matter had received attention and that further co-operation could be expected. More school names were supplied in the second half of the year and it was decided to set the deadline for submission as 31 December 2001.

Of the 1 800 Kits donated directly to provincial authorities only 1 203 school names had been supplied by December 2001. Progress had been made in Free State, Eastern Cape, KwaZulu-Natal and Northern Province although names from some districts/regions were still outstanding. Information was still awaited from North West where, despite a good initial response, no further progress occurred in the second half of the year. Although more Kits were allocated in Gauteng during the second half of the year, it was reported that a considerable number of Kits went missing during relocation of the provincial office.

Table 3.4 Addresses obtained for *MapTrix* Survey from provinces

Province	School names supplied	Addresses supplied	Names without addresses	Names do not match with EMIS	Names and addresses traced	Duplicate school names*	School addresses generated**
Eastern Cape	211	**42**	169	45	124	25	**145**
Free State	125	**21**	104	15	89	2	**87**
Gauteng	128	**0**	128	21	107	2	**108**
KwaZulu-Natal	213	**121**	92	12	80	7	**83**
Limpopo	163	**46**	117	10	107	2	**108**
Mpumalanga	104	**0**	104	15	89	3	**92**
Northern Cape	57	**0**	57	8	49	6	**55**
North West	55	**0**	55	10	45	4	**47**
Western Cape	147	**0**	147	20	127	7	**133**
Totals	1203	**230**	973	156	817	58	**858**

*School names in the EMIS database with two or more addresses in the same province
**Three addresses later proved to be incomplete

Although the names of 1 203 recipient schools had been provided, only 230 addresses had been supplied leaving 973 missing addresses. Already postponed once, it was necessary to seek the address information elsewhere so that the survey could go ahead. An Access database was created using the names that had been supplied and this was matched with the Education Management Information System (EMIS) of the national Department of Education. Initially 369 of the 973 names were rejected. Names were corrected manually but 156 names could still not be matched with those in the database (Table 3.4). Further investigation showed that this was due to irresolvable differences in spelling and school classification. A total of 58 duplicate names were found, 25 of which were in the Eastern Cape. Questionnaires were sent to all schools with the same name, as there was no mechanism to differentiate between schools with the same name in the same province. A total of 858 addresses were found to match school names supplied by the provincial education authorities. Using the 200 competition winners (Table 3.3), the 230 school names supplied with addresses plus the 855 sourced from EMIS, a total of 1 285 recipients were eventually identified for the despatch of questionnaires.

3.5.2 The evaluation instrument – an opinion questionnaire

While the address data were awaited, the questionnaire was designed, piloted and prepared for postal despatch. The evaluation of the learning material was conducted using a postal questionnaire survey (Appendix 3.1). Following the guidelines of Bless and Higson-Smith (1995) a draft questionnaire was drawn up covering various issues: the practical (access to the materials), demographic (educator and learner profiles), behavioural (tasks and performance) and attitudinal or perceptual (positive or negative impact or response). Because attitude to an innovative educational intervention strategy is likely to influence adoption rates (Lotz, 1996), it was decided to incorporate attitude scales into the survey questionnaire. These were included so as to produce a measurable attitude score and to identify particular strengths and weaknesses in the programme and learning materials.

A pilot survey was conducted with six educators at schools in the local area (Western Cape). The schools selected ranged from extremely well-resourced to one with minimal resources. Structured face-to-face interviews were conducted with three educators; structured telephone interviews were conducted with the others who had each received the draft questionnaire for close scrutiny beforehand. All participants were asked to comment on the clarity of the questions and their suggestions were later incorporated into the final document. An educator from an under-resourced school advised that questionnaires should be addressed to the school principals, not senior geography teachers. He intimated that, because of the strict hierarchical authority structure in many schools, unless a task was assigned by the principal it would not be undertaken. (The efficacy of this suggestion was later disputed in the light of the low rate of questionnaire returns.)

Table 3.5 MapTrix Questionnaire: analysis of question type and number

Section	Tick responses	1 or 2 words or numbers	Comments (phrases, sentences)
A. Access to MapTrix and personal details of educator	17 (10)	2 (1)	2
B. Educator's evaluation of attitude and behaviour of learners	20	3 (3)	4
C. Further development of the MapTrix learning programme	4		
D. Educator's evaluation of the MapTrix programme and procedures	28 (3)	8	2 (2)
E. Educator's evaluation of existing MapTrix components	10	4 (4)	2 (2)
Totals	**79 (13)**	**17 (8)**	**10 (4)**

The structure of the final questionnaire is presented as Appendix 3.1 and summarised in Table 3.5. The original document comprised four A4 pages although the majority of answers required only a tick (ü) or cross (û). The figures in brackets indicate the number of answers that could be eliminated as options, depending on prior responses (e.g. If your answer is NO, please explain).

3.5.3 Despatch of the questionnaires

Questionnaires were posted by the end of January 2002 to the 1 285 schools for which addresses had been sourced. Two address labels were generated for each school. One was for the envelope and the other was stuck onto the questionnaire so that returns per province could be monitored. Self-addressed, pre-paid envelopes were included for the returns. Provincial education authorities were advised that postal delivery of questionnaires to schools could be expected early in the first term and completion and return was requested by the end of term (April 2002). Examples of the questionnaires were enclosed with each letter.

Lists of school names continued to arrive after the questionnaires had been posted out, 125 of which had addresses. Another posting brought the total to 1 410 questionnaires despatched. By the deadline at the end of April, only 97 questionnaires had been returned. Further telephonic contact with geography education officials gleaned more names (with addresses) and some interesting information. In some cases, Kits were awarded to teachers that attended the *MapTrix* presentation ceremonies or follow-up training sessions. Often these were not under-resourced schools. There had been complaints that the questionnaire was too long, teachers did not understand the questions or did not have time to fill in answers. Some Kits earmarked for under-resourced schools had been allocated to schools with adequate resources because it was just more convenient to do so. Where schools could not ensure that the materials would be secure, geography subject advisors were reluctant to hand them over. Alternately some Kits were allocated to schools as a reward for improving their security arrangements.

In other cases, geography subject advisors were so positively disposed towards *MapTrix* that they had arranged the purchase of additional Kits for the schools under their jurisdiction (Western Cape, Northern Cape and two regions in KwaZulu-Natal). Some had photocopied the questionnaire and handed these out at training sessions with teachers. As these were distributed without address stickers or instructions to fill in school details, it was not possible to ascertain which province they were from when they were posted back. Questionnaires continued to trickle in, the last batch arriving in July 2002.

3.5.4 Number of responses to the questionnaire survey

The response to the survey was disappointing, only 178 were filled-in and returned. Of these, evaluation of *MapTrix* was completed on only 92 (Table 3.6). Although so much effort had been expended in getting addresses for 1 410 schools, more than 1 200 or 85 % did not respond. Nevertheless, data from the returned questionnaires was collected and evaluated providing significant insights into the use of *MapTrix*.

Table 3.6 Comparison between possible and actual questionnaire returns

<table>
<tr><td colspan="6">2000 MapTrix Kits donated by DLA</td></tr>
<tr><td rowspan="3">590
Insufficient school information received from provincial education authorities</td><td colspan="5">1410
School names and addresses received, questionnaires despatched</td></tr>
<tr><td rowspan="2">32
Envelopes returned - incorrect addresses</td><td rowspan="2">1200
No response from schools</td><td colspan="3">178 Questionnaires returned</td></tr>
<tr><td>55
Kits not received by schools</td><td>31
Kits received but not used</td><td>92
Kits used - evaluations completed</td></tr>
</table>

On 55 of the 178 questionnaires that had been returned, teachers indicated that they had not received a *MapTrix Kit*. Amongst the reasons for this could be: allocated Kits had not yet been delivered, questionnaires were sent to all schools with the same name in each province (see Section 3.5.1) of which only one would have received a Kit. The fact that 31 schools had received Kits that had not been used yet was another cause for concern.

3.6 RESULTS

3.6.1 Educator profile and map use teaching resources

On the first page of the questionnaire (Appendix 3.1) dealing with access to learning materials, teaching aids and educator training were evaluated. The questions were of a general nature and could be answered by all 178 educators who responded to the survey whether they had received a *MapTrix Kit* or not (see Table 3.6). Their answers were used to gain insight as to the challenges facing geography educators in under-resourced schools. These findings are discussed in Chapter Six as part of the broader issue of educators' preparedness to meet spatial learning needs.

3.6.2 Learner profile

Data for the learner profile could only be gathered from the completed questionnaires. The survey showed that educators used *MapTrix* with more than 10 000 learners in nearly 300 classes of greatly varying size, ranging in level from Grade 8 to Grade 12 and speaking a wide variety of languages. On average, each educator was responsible for teaching map reading to 112 learners. The breakdown of learner numbers is presented in Table 3.7.

Table 3.7 Range and size of classes that used *MapTrix*

Grade	**8**	**9**	**10**	**11**	**12**	**Total**
Learners (total)	337	546	2744	3337	3347	**10 311**
Classes (total)	10	16	73	92	105	**296**
Maximum	40	48	102	84	62	**102**
Minimum	29	20	13	14	5	**5**
Average no. per class	34	34	38	36	32	**35**
Times Grade was re-commended for *MapTrix*	**9**	**15**	**57**	**54**	**52**	

Because the language used for lessons, explanations and exercises has an important impact on the adoption of a self-instruction programme, educators were asked to identify the home language of the majority of their learners as well as their preferred medium of instruction (see Table 3.8). During the classroom trial of the prototype of *MapTrix* (Innes, 1998) it was found that the only characteristic that had a significant impact, causing differing rates of progress, was the mother tongue of learners. The impact of large classes combined with the language barrier is discussed below.

Table 3.8 Language of teaching and learning

Mother tongue of majority of learners	**Number responding**	**Language of teaching**
Afrikaans	23	Afrikaans
IsiZulu	18	English
Sesotho	17	
English	11	
IsiXhosa	8	
Setswana	7	
Xitsonga	4	
Siswati, IsiNdebele, Sepedi, Tshivenda	4 (x 1 each)	
Total	**92**	

3.6.3 Attitude scales used to evaluate *MapTrix*

Only the 92 evaluations that had been completed could be used to provide data for the attitude rating scales embedded in the questionnaire (Appendix 3.2). These were constructed to elicit 20 *yes* or *no* responses. In the first attitude rating scale, 7 responses were related to learner attitude (A3.2.1), and 13 to learner behaviour (A3.2.2). In the second rating scale, 14 responses related to educator attitude (A3.2.3) and 6 to educator behaviour (A3.2.4). *Yes* responses to half the statements/questions contributed to a positive score while *no* replies to the other half indicated a positive evaluation. To elicit a maximum positive attitude score of 20 points, educators would agree with all the questions worded to elicit a positive response and disagree with all those worded negatively (e.g. when evaluating learner behaviour '*did the majority of learners have difficulty finding the correct answers on the maps?' - no*ü). The twenty items and preferred responses are listed in Appendix 3.2 with the number (and percentage) of educators that selected them. The total scores are summarised in Tables 3.9 and 3.10.

3.6.4 Learners' attitudes to *MapTrix*

Teachers were asked to monitor the general attitude and behaviour of learners while they used *MapTrix* and on completion of the programme to enquire what they had liked and disliked. The majority of educators (85 %) rated learner attitude and behaviour positively, of which 40 % were very positive and 11 % were strongly positive (Table 3.9). Most educators (95 %) agreed that the majority of their learners had enjoyed the *MapTrix* periods, especially marking their own answers (89 %).

Table 3.9 How educators rated learner attitude and behaviour

Score	Attitude category	Number of educators	Percent
0 – 10	Negative	14	15.2
11 – 14	Positive	31	33.7
15 – 17	Very positive	37	40.2
18 – 20	Strongly positive	10	10.9
Total		**92**	**100.0**

Educators' perceptions of learner behaviour generally scored lower than attitude. However, 83 % of the educators indicated that the majority of learners efficiently and independently followed the self-instruction procedure once they became accustomed to it, easily found the answer cards to match their work cards (79 %) and then marked their answers strictly according to the answers provided (76 %). Comments revealed that the learners' favourite components included the full-colour symbol illustrations and maps. They also liked the self-instruction methodology (e.g. 'it's easy', 'it's like playing') and activity based learning (e.g. 'the chance to practice'). Dislikes (noted on only 27 % of evaluations) included objections to the material not being in the mother tongue of learners, that questions were 'tricky' and there was 'too much reading'.

3.6.5 Educators' attitudes to *MapTrix*

Educators rated their own attitude and behaviour when using *MapTrix* even more favourably than that of their learners, 97 % viewed the programme in a positive light with 46 % very positive and 20 % strongly positive (see Table 3.10). The item on which there was the highest degree of concurrence (97 %) was that educators would use *MapTrix* again, 94 % indicated that they would not discourage other educators from using the programme. When given the opportunity to comment on the advantages of self-instruction, 35 % of educators referred specifically to improved understanding of learners (including: improved confidence, skills, practical ability and synonymous phrases) and 19 % referred to learner independence (including: self-motivation, active participation, discovery, enquiry and synonymous phrases).

Table 3.10 How educators rated their own attitude and behaviour

Score	**Attitude category**	**Number of educators**	**Percentage**
0 – 10	Negative	3	3.3
11 – 14	Positive	29	31.5
15 – 17	Very positive	42	45.6
18 – 20	Strongly positive	18	19.6
Total		**92**	**100.0**

More than 90 % of educators agreed on the following points (see A3.2.3):

- Learners' map reading skills had improved.
- Basic geography concept comprehension had improved.
- The programme could be used as extension material for fast learners in lower grades.
- *MapTrix* was a more efficient method of improving map reading than other methods they had tried.
- The programme met the need for outcomes based learner support material for topographic map reading.
- Their own attitudes towards teaching this skill had improved while using the programme.

Despite their favourable responses and comments, the majority of educators (59 %) would prefer the programme in textbook format. Just over half (51 %) indicated that there were too few cards to keep all learners busy. Despite the fact that 88 % felt that the *MapTrix Educator's Guide* provided full and clear instructions, 49 % felt anxious because the first few periods seemed a bit disorganised. 53 % expressed a concern that they were too busy administering the programme to help below-average learners. The two disadvantages of self-instruction that many educators raised were that self-instruction was too time consuming (29 %) and that learners were dishonest i.e. they cheated or copied (26 %). Not having the learning materials in their learners' mother tongue was problematic for 24 % of respondents.

3.6.6 Time taken to complete the *MapTrix* programme

MapTrix was designed for teaching topographic map reading; to be used by one to a maximum of forty learners working simultaneously; for approximately twelve learning periods. While it is clear that educators felt that map reading was improved, this was generally not possible in the timeframe envisaged. The average length of geography learning periods was 44 minutes ranging from 30 minutes to a maximum of 60 minutes. Because of this range it is difficult to quantify the average time taken to complete the programme but learners of all ability levels generally took longer than anticipated. 51 % of educators indicated that the majority of learners failed to complete the programme in the twelve learning periods recommended.

The fact that many class sizes were far larger than recommended probably led to individuals having to wait for required work cards, protracting the time unnecessarily and possibly contributing to the low completion rate. Only 45 % of educators agreed that there were enough work cards in the Kit. Some educators (25 %) felt there were not enough work cards on each topic; some suggested that more should be included for the Landscape section.

3.6.7 Language of learning materials

Of the different language groups represented, the largest group of teachers who returned the questionnaires (25 %) were Afrikaans speaking; 18 of them felt that *MapTrix* should be translated into Afrikaans. Only 4 of the 58 educators teaching Geography to learners, who speak a traditional African language at home, requested translation. This supported the opinion of the educators interviewed in the pilot study who believed that having all material in the language of the final examinations would afford learners the opportunity to practice map reading under examination conditions thus improving their scores. The slower pace associated with second language learning probably contributed to the extended time required for the programme.

3.6.8 Further development of the *MapTrix* programme

Designed as an introductory programme for map reading, *MapTrix* does not meet all the needs of learners preparing for the matriculation practical examination paper for Geography, yet 47 % of educators felt that it did so. (This is reflected in Table 3.7 where educators recommended Grade 12 almost as often as Grades 10 and 11 as the most suitable Grade for using *MapTrix*.) However, 95 % concurred that a self-instruction programme for map and photo analysis and interpretation would be helpful. This disparity may stem from the fact that for educators from under-resourced schools the priority has been just getting candidates to pass the practical examination, rather than ensuring that they master the full range of map use skills.

Although the majority of educators evidenced a positive attitude to the programme, 59 % indicated that they would prefer the learner support material in textbook format. Unfortunately providing a wide range of full colour map extracts and symbol illustrations in textbook format for each learner would be prohibitively expensive. In response to a question about whether conversion of *MapTrix* to a computer-based learning programme would render it useful in schools, it was encouraging to find that 48 % of responding schools had computer terminals available to learners.

3.6.9 Educator collaboration in the development of advanced learning materials

The last section of the questionnaire carried an invitation to educators to collaborate in the development of learning materials for map and photo analysis and interpretation (see last page of Appendix 3.1). While 66 % of educators indicated that they would like to participate in the development of an advanced version of *MapTrix*, only 3 % correctly followed the instructions for selecting work cards in order to participate in this process. This finding was most disappointing, as the proposed collaborative writing process would have relied heavily on written instructions to co-authors. Although this attempt at collaboration was abandoned, another attempt is reported in Chapter Six.

3.6.10 Problems encountered with education administration structures

There were problems related to both inter- and intra-departmental co-operation. *MapTrix Kits* were donated by the Department of Land Affairs to the Department of Education with limited prior knowledge or discussion. This meant that there was no official channel in place for dialogue and planning. While the Minister of Education supported the initiative and expressed sincere gratitude and some Provincial education executives followed his lead, middle management was not adequately informed of the procedure for allocating and distributing the learning materials. Valuable contact was made with geography education stakeholders at provincial presentation ceremonies for which invitations had been broadly circulated. It is largely due to such individuals that it was possible to obtain some degree of co-operation in conducting the survey. Unfortunately, attendance ranged between four people (Gauteng) to more than sixty (Eastern and Western Cape). The significant degree of upheaval that was taking place, as education departments were being rationalised and streamlined, meant that many newfound contacts were soon lost.

Like the departmental management structures, the management of school data was also in a state of flux. At the beginning of 1994 there were a myriad of departments responsible for education in South Africa. As discussed in Chapter One, there were three departments each (for 'white', 'coloured' and 'Indian' schools) in four provinces plus a nationally managed department for 'black' schools. Following the elections that heralded in the 'new' South Africa, data from all these structures was combined into one database (EMIS). It is not surprising that school names were difficult to trace. Erroneous records made it impossible to match all names. Historically, the name of a town was sometimes given to schools for each of the divided race groups leading to more than one school with the same name. School categories also differed with the terms high school, senior school, secondary school, senior secondary school, combined school and college being used. At the time of the survey, regional and district offices did not yet have access to the database from which to supply addresses for schools.

3.7 DISCUSSION

3.7.1 Number of Kits per class

In some cases, individual Kits provided insufficient learning materials for a class. To accommodate large class sizes, two *MapTrix Kits* can be used simultaneously. All work cards and answer cards in the additional Kit can be earmarked to facilitate management and control of the learner support material. Additional resources would reduce learners' waiting time between exercises and thus the time taken to complete the programme. This would also ensure that all learners were engaged in active learning and release the educator to assist slow learners.

3.7.2 Language of the self-instruction programme

There are only two languages used for teaching in South African Secondary Schools, English and Afrikaans. One of the flash points that led to the Soweto Uprising in 1976 was the attempt by the Nationalist Government to force Afrikaans as the language of instruction on all Black learners

(Wesso and Parnell, 1992). No traditional African languages are used as the language of instruction; the majority prefer to attend English schools (see Table 3.8) rather than Afrikaans schools. To address the needs of the Afrikaans learners, a digital conversion of the MapTrix programme has recently been completed with both English and Afrikaans versions on the CD. The beta version of this programme was used to prepare learners for the trials of the map analysis programme (see Chapter Eight).

3.7.3 Advanced version of *MapTrix*

In order to reduce the cost of a learning programme for developing advanced map use skills it was originally proposed that a second set of 52 advanced exercise cards be developed for use in conjunction with the maps on the existing *MapTrix* work cards. The advanced cards would carry illustrated lessons for analysing and interpreting spatial information on the reverse. It appears from the survey that the loose card format may not meet geography educators' needs, as the majority would prefer to have *MapTrix* in a textbook. No opportunity was given for educators to give reasons for this preference but in subsequent discussions with teachers it has become clear that they were concerned that learners had no notes or exercises for revision. Some found that management of the many components was onerous and that the answer cards got lost too easily.

3.7.4 Computer facilities

The finding that a significant number of responding schools were equipped with computer facilities suggests that the development of a computer-based learning programme for advanced spatial skills may be a viable option. The high cost of printing full-colour maps and illustrations can be avoided by providing these in digital format along with animated graphic explanations of the more complicated aspects of advanced map use. The potential for using this medium to unravel the complexities of the mathematical competencies required for spatial analysis is particularly appealing. It is only in the digital medium that Geographic Information Systems (GIS) and Global Positioning Systems (GPS) can be fully illustrated and explained. Both the latter are included as learning content for Geography in the NCS for FET (DoE, 2003).

Where computer facilities do not yet exist, supplementary notes, examples and exercises, based on the proposed digital programme, could be compiled into a handbook. This could be used in combination with the *MapTrix Kit* and a video, compiled from animations and movie clips, to provide access to learning.

3.7.5 Lack of geography education support structures

The lack of a channel of communication through which to reach all stakeholders in geography education was sorely missed. It appeared from discussions that in many cases officials appointed to manage the delivery of geography education were not geography specialists. They therefore had little appreciation for the unique needs of the subject, especially as they pertained to the development of spatial competence. While small groups of teachers may pool resources and ideas at town or district level, there is currently no national geography teachers association. It is strongly recommended that the initiative be taken (perhaps by the Society of South African Geographers) to investigate the formation of such a support structure. Such an association could prove extremely valuable to geography teachers, examiners, advisors and administrators at this time when radical changes are being introduced into the geography curriculum.

3.8 CONCLUSION

Investigation into the placement of the learning materials revealed that about 400 *MapTrix Kits* could not be traced, even eighteen months after the donation was made. Many school names provided could not be traced in the Education Management Information System (EMIS). Many months after Kits had arrived at some schools; they had still not been used. These factors and apathy meant that a low percentage of participants completed the evaluation of the learning materials (only 92 educators out of the possible 2000 for whom the Kits were intended). Perhaps the most disappointing of all is the lack of commitment to collaborate in the further development of the learning materials for photo and map analysis and interpretation. Even educators that showed some interest, failed to follow the instructions for initiating the collaboration process.

The main aim of the survey was to evaluate *MapTrix* as a self-instruction method for improving the topographic map reading ability of learners in under-resourced classrooms in South Africa. The sample population is small and possibly skewed so findings may not be fully representative of under-resourced schools where Geography is offered to Grade 12. However, high attitude rating scores and positive free-response comments indicate that map reading (along with general geographic concept comprehension) was improved by the use of the *MapTrix* self-instruction programme. The positive attitudes of educators (97 %) and learners (85 %) bode well for wide adoption of the programme. Large class numbers and difficulty with the language of the learning materials caused the time period required to master basic topographic map reading to be longer than anticipated. Two Kits can be used simultaneously to solve the problem of numbers. Translation has been considered to make the learning material more accessible.

It appears, from the opinions of educators, that self-instruction can be used to help solve the problem of poor map use performance, even at under-resourced schools in South Africa. This methodology may be used to improve basic spatial competency as required for the General Education and Training Certificate. The development and evaluation of learner support material for the higher order skills of spatial information analysis and interpretation are necessary if the needs of Further Education and Training candidates are to be met. Such materials could potentially help anyone of any age that needs to read spatial information whether for tertiary studies, in the work place or for recreation purposes, giving them a firm geographic concept base on which to build analysis and interpretation skills. The findings reported in this chapter make a considerable contribution to the design phase of the research process (Figure P.1).

CHAPTER 4

INFLUENCE OF SCHOOL MATHEMATICS AND GEOGRAPHY ON MAP ANALYSIS SKILLS

"Imagine you're lying on sand. Feel how your body sinks down into it, how the sand gives way to your body. Now, think of the map your body makes in it."
No!
"A map is different.
A map converts, scales down, represents space and the things in that space in a symbolic way."
Alexander, 2000: 187

4.1 INTRODUCTION

In order to analyse the spatial information gleaned from reading a map, certain basic mathematical competence must first be attained (Boardman, 1985). Before developing learner support materials to teach map analysis, the degree to which Mathematics and Geography impact on learners' ability to perform map analysis tasks was evaluated. This chapter reports on an exploratory investigation conducted with first year students at a South African university to find out whether their prior school learning experiences in Mathematics and Geography had prepared them to analyse the spatial information on topographic maps.

4.2 BACKGROUND

4.2.1 Literature review

In searching for an appropriate method for teaching topographic map use skills, the work of a number of researchers was consulted. Boardman's (1983) seminal work on the development of graphicacy and subsequent texts (1985, 1986) are especially pertinent. He suggests that mathematics concepts 'should be developed in such a way that pupils are familiar with the appropriate mathematical ideas by the time they are needed in other subjects' (1985: 15) which would include map use in Geography. He identifies three successive categories of map use skills as a) *reading and calculation*, b) *transformation* and c) *interpretation* (1986: 135) referring to the first as '...basic skills (that) should have been learnt lower down the school'. This appears not to be the case in South Africa where map use has been identified as a significant problem in geography education at secondary level over many years (Magi, 1981; Ndlwana, 1991 and others) and is confirmed by the assessment of geography matriculation examination results discussed in Chapter One. Student difficulties with maps continue at tertiary level, as reported by Davies, 1988; McGee *et al.*, 1995; Sekete, 1995; Liebenberg, 1998 and Tshibalo and Schulze, 2000.

Much research (summarised by Ormeling, 1996a) following Boardman's early work indicated that his *calculation* and *transformation* tasks could be grouped as map analysis. Boardman suggested that map *interpretation* '...demands an ability to understand the relationship between the physical and human geography of the area shown on the map' (1986: 135) and, furthermore, that the study of these relationships should be undertaken only by older learners. In an attempt to prepare novice map readers, whether at school or in the workplace, for this higher level map use activity, four components of the physical/human geography relationship have been identified (Innes, 1998; Innes and Engel 2001a) and used to provide a geographic frame of reference for learners to use when first working with topographic maps. Initially following Smit's (1994) approach of using the five standard colours of the map symbols on the South African topographic map to identify certain geographic themes (e.g. blue for drainage, brown for relief etc) it was found to be more useful to use the concepts: physical landscape, rural settlement, urban settlement and transport infrastructure as organising concepts (Innes, 1998 and 1999b).

In common with young people in many countries, it is often suggested that they cannot perform what is usually referred to as map *reading* (Innes, 1998). The investigation reported in this chapter, however, suggests that the problem in South Africa may lie not so much with teaching map reading as such but with teaching what Boardman (1986) defines as *map calculation* and what is referred to in this study as *map analysis*.

4.2.2 Mathematics in the South African school curriculum

As explained in Chapters One and Two, education in South Africa has been engaged in a process of radical curriculum reform during the period of time that this investigation has been underway. Until 2005, South African learners in senior secondary classes generally took a minimum of six school subjects, of which two - a first and second language - were compulsory. The balance of the subjects could be selected from a wide range of options. The school leaving examination, the Senior Certificate (commonly referred to as matric), was usually written at the end of the twelfth year of schooling – Grade 12. With the implementation of outcomes based education (OBE) and the national qualifications framework (NQF) from 1997, children are required to start school in a reception year (Grade R) before advancing to Grade 1 (see Table 1.2). Since 2006, learners entering Grade 10 in the further education and training (FET) band are required to take seven school subjects of which four are compulsory. These include their Home Language and one Other Language, either Mathematics or Mathematical Literacy (all examined externally) plus Life Orientation (examined internally). Three optional subjects must be selected over and above these compulsory offerings totalling seven, one internally assessed subject and six subjects examined externally for the National Senior Certificate (NSC) (DoE, 2005). These changes mean that, from the end of 2008, every South African child has the opportunity to receive 13 years of schooling, of which ten years are compulsory (Van Harmelen, 1999), and this schooling will include at least some form of instruction in Mathematics. This is a far cry indeed from the days when children classified as Black did not receive state-subsidised education beyond primary school and when there was '...a belief that a restricted curriculum, offering less range and depth, was more appropriate for the needs of particular groups' (Clark, 1989:48).

4.2.3 Hypothesis and assumptions

To test the hypothesis that the teaching of Geography and Mathematics at high school level has a positive influence on topographic map reading and analysis it is necessary to explore the following assumptions regarding topographic map use performance:

(i) Students who have passed matriculation Geography perform better at topographic map use, including reading and analysis, than those who did not take Geography at school.

(ii) Students with matriculation Mathematics perform less well at map reading but better at map analysis than those without Mathematics.

(iii) Students with both Geography and Mathematics perform best at map reading and analysis relative to those with other subject options that include Mathematics, Science and Geography.

No distinction was made between students who had taken the school subjects at higher or standard grade.

4.3 MATERIALS AND METHODS

4.3.1 Population sample

203 students were registered for an introductory course in Environmental and Geographical Science in the first semester of 2003 at the University of Cape Town (UCT). One of the course prerequisites was that they should have attained a passing grade (40 %) in Geography, Mathematics or Science at matriculation level (on either higher or standard grade). During four afternoon practical sessions ending in the first week of April 2003, the students (in four groups of approximately equal numbers and pre-requisite subject mixes) each attended a two hour information session before attempting a map reading and analysis test designed to assess the impact of their school Mathematics and Geography learning experiences on their topographic map use performance. On completion of the evaluation it was found that, of the 203 registered students, three had not attended, six failed to record their pre-requisite school subjects, four did not give their finishing times and the results of two students who gained zero scores (and later changed courses) were withdrawn to avoid skewing the results. This left 188 participating students, the breakdown of their pre-requisite school subjects is given in Table 4.1.

Table 4.1 Numbers of students per subject group

Students per group based on matriculation subject pre-requisites	Abbreviation	Number per group	Totals
Geography, Mathematics and Science Geography and Mathematics, Geography only	GMS GM G	80 27 10	
All students with Geography	**All with G**		**117**
Mathematics and Science Mathematics only	MS M	59 12	
All without Geography	**All without G**		**71**
Total			**188**

4.3.2 Intervention procedure

Because the student population that participated in this exploratory research had widely differing school experiences, it was assumed that a significant proportion would not have studied a topographic map sheet before and would therefore need some introductory information before attempting any test of their ability to read and analyse one. Rather than the *pre-test – intervene – post-test model* used to evaluate the *MapTrix* prototype (Innes, 1998), the more simple *intervention – test model* was used here (Bless and Higson-Smith, 1995).

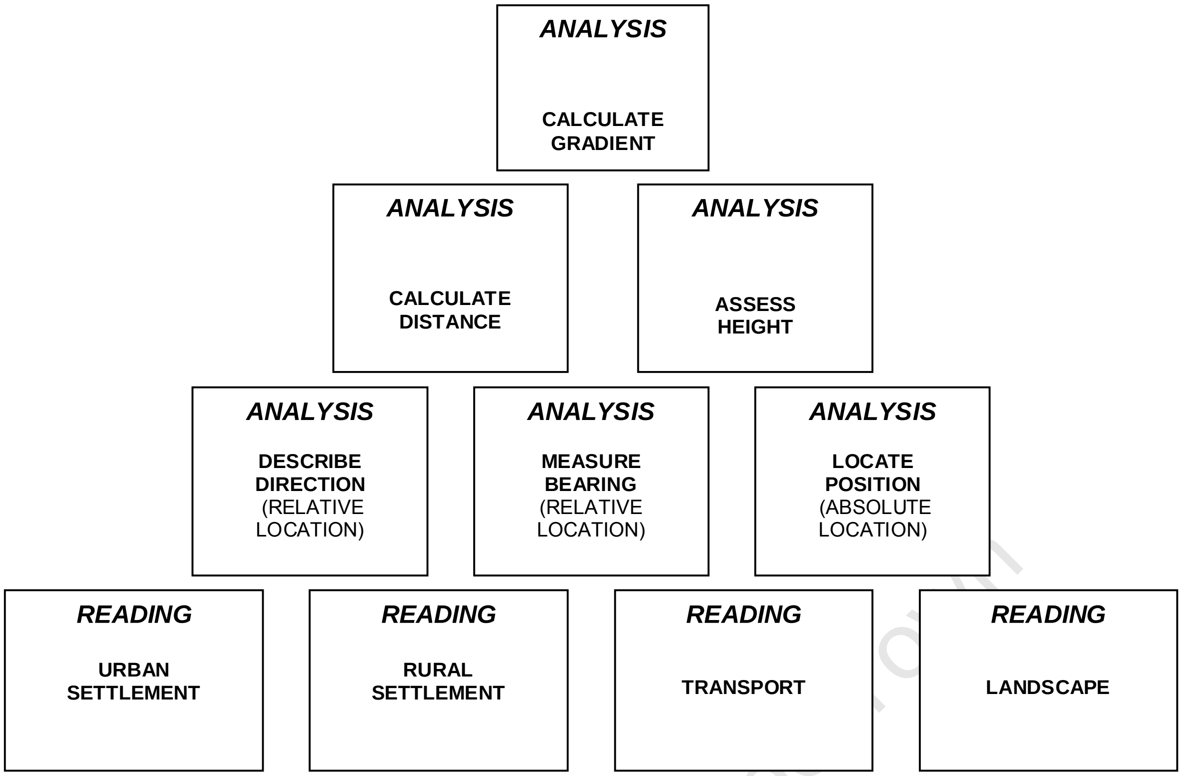


Figure 4.1 Pyramidal hierarchy of map use skills (after Innes, 1998)

The skills hierarchy illustrated in Figure 4.1 was used to explain to the students that spatial information must be read with understanding (represented by the four blocks at the base of the skills pyramid) before a ranked series of map analysis tasks can be undertaken. Progressing up from the base, the next skill level in the hierarchy is finding places on a map (represented by the tasks in the next three blocks). These tasks are considered equally difficult and competence should be demonstrated before attempting tasks at the next skill level. Once they can identify and find places, measurements can be taken (next two blocks), making comparisons possible (the top block). Only once spatial information about a landscape has been analysed, can the true nature of its people/place interface be interpreted.

A video illustrating and explaining the South African 1:50 000 topographic map symbols was shown (CDSM, 1997a). Students were then divided into four groups, each to focus on one of the themes illustrated by the four blocks at the base of the pyramid in Figure 4.1. Each group included some members who had completed Grade 12 Geography at school and could be assumed to be familiar with topographic maps, thus enabling them to assist novice map users. Each group was directed to free-search and discuss one of the four quadrants (either the NW, NE, SW, or SE) of a topographic map of the Cape Peninsula (CDSM, 2003), which includes the location of the university and surroundings. After the small-group discussions, a student from each group was selected to report to the class on the group's theme (either rural settlement, urban settlement, transport or relief) relative to the map quadrant they had been instructed to study.

After the report-back, lecturer-directed class discussion then encouraged comparisons across the themes for the whole map area to identify similarities and differences between parts of the area surrounding the site of the University, as well as how these themes impact on one another (e.g. how relief influences urban morphology). This activity provided all students with an opportunity to read the local topographic map using a geographical concept 'filter' to avoid the confusion often experienced by first time topographic map users. They also verbalised the terminology related to the human and physical geography found at the people/place interface which is so well represented on a topographic map.

Following a demonstration as to the use of an alphanumeric grid, together with instruction in respect of the cardinal points of a compass, the difference between relative and absolute location was explained. Measurement of the angle of true bearing was illustrated and practised using a 1:50 000 topographic map sheet adapted for map use training (CDSM, 1997b). Students were then guided in the identification of features using geographic co-ordinates on the same map.

4.3.3 The assessment instrument and recording procedure

Having given the students this brief introduction to topographic map study, an introductory level map use test was administered. On the test cover sheet, each student was asked to indicate which of the pre-requisite school subjects they had passed. They were also instructed to note their starting and completion times. A 5' x 5' extract of the 1:50 000 topographic map covering part of the city of Cape Town was used for the test. The map shows the University of Cape Town and its environs, it was selected from the 52 map extracts on the work cards in the *MapTrix Kit* (Innes, 2000) and is identified by the Ace of Clubs (Appendix 4.1).

The first part of the test was based on the ten basic map reading questions on the *MapTrix* work card; students were expected to answer all of them. Ten further questions were set to test map analysis (Appendix 4.2). Of the latter questions, the students were asked to select only those five tasks that they felt confident enough to complete. They included: finding location using geographic co-ordinates, measuring bearing, identifying contour lines, measuring straight line distances, calculating, first, difference in elevation on a slope and, then, gradient, identifying different land uses along a cross-section of the map area and calculating the scale of a vertical aerial photograph of UCT campus (see similar image at a smaller scale in Appendix 4.3). Students were allowed as much time as they needed to complete the test and were free to leave once they had completed the map reading test and the five map analysis tasks that they had selected.

Both the map reading and the analysis questions were constructed so that there could be only one correct answer. A marking memorandum was prepared and independent assessors were assigned to mark the test papers. Test scores and time taken were recorded. Once the data had been sorted according to groups of students with the pre-requisite subject combinations, the mean scores for map reading, map analyses (and a total score for map use) as well as the time they had taken to complete the test, could be calculated. Student performance was evaluated using both scores (indicating accuracy) and time taken to complete map use tasks (indicating efficiency). The mean scores are compared to assess whether prior learning at school has any influence on map use performance.

Apart from the fact that this investigation is not central to the thesis, the results of the analyses, illustrated in Figures 4.2, 4.3 and 4.4, were not tested for significance for two reasons. The investigation was carried out to ascertain whether school Mathematics was impacting on map skills because, if so, this would influence the structure of the map analysis learning programme (i.e. the inclusion of mathematics sub-lessons - Chapter Seven). Because students could select only those map analysis tasks that they felt confident enough to tackle, the scores for map analysis did little to reveal the true nature of the map analysis problem.

4.4 RESULTS AND DISCUSSION

4.4.1 Map reading, map analysis and overall map use

The mean map reading score for all students assessed was 7.99 (79.9 %), ranging from 8.40 (84 %) for those who had taken Geography as the only prerequisite subject down to 7.61 (76.1 %) for the Mathematics and Science Group (Figure 4.2). Topographic maps are generally considered difficult to read because of the complex array of the features they display (Boardman, 1983). In this investigation it was found that, with only minimum intervention using a geographic concept filter and vocalisation of the learned concepts, even students who had no previous experience of using a topographic map were able to read the map with relative ease, confirmed by the high mean test scores for the basic map reading test.

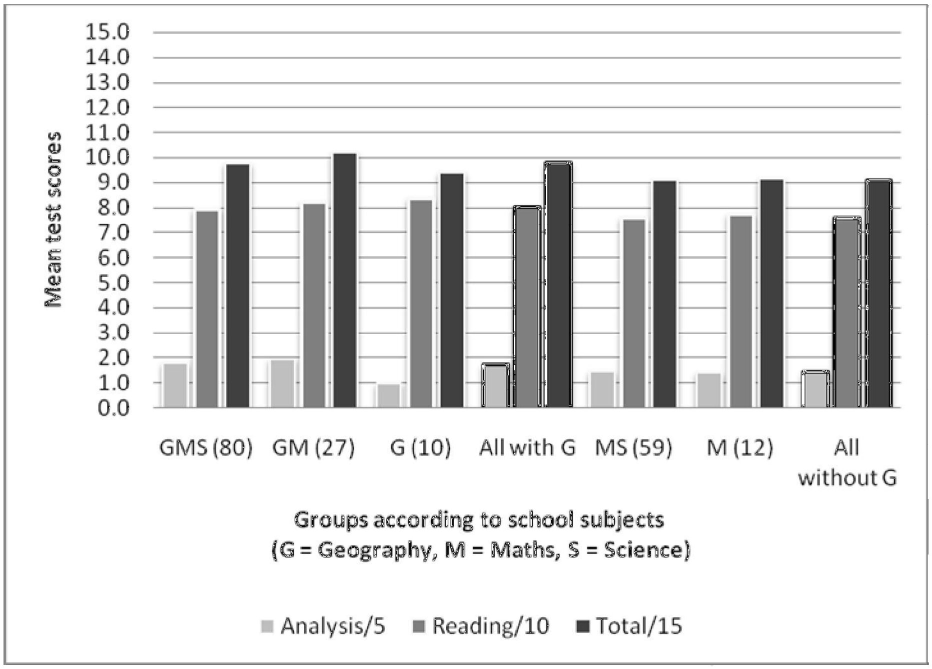


Figure 4.2 Comparison of mean scores for topographic map use tests by groups of students with different subject combinations; count per group in brackets. (Geography group n = 117; non-Geography group n = 71)

Figure 4.2 illustrates, however, that the scores for the map analysis tasks were much lower. No group attained a mean score of 2.5 (50%) which would be considered a pass mark at tertiary level. This poor level of performance is exacerbated by the fact that the students were given the option to select *only* those five tasks that they felt confident enough to tackle. The highest mean score was attained by the Mathematics and Geography group; 1.96 (39.2%). The lowest mean score, 1.0 (20%), was attained by the students who had taken Geography only. The map analysis mean score for all students who had taken Geography (with or without other pre-requisite subjects) was 1.78 (35.6%) while those who had not taken Geography scored 1.46 (29.2%).

When combining the map reading and analysis test scores, Figure 4.2 shows that the group that performed best overall had taken both Geography and Mathematics to Grade 12; these students achieved a mean total score for the test of 10.22 (68.1%). The mean score for all those that had taken Geography was 9.83 (65.5%). The overall map use score for all students who had not taken Geography was 9.1 (60.7%), only 0.73 (4.9%) lower than those who had completed Grade 12 Geography.

4.4.2 Comparing map reading and map analysis scores

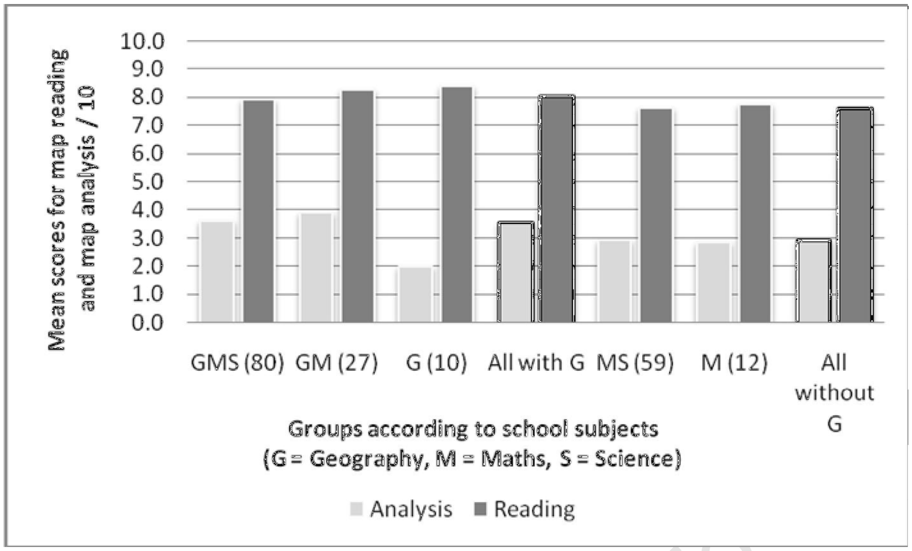


Figure 4.3 Comparison of mean map reading and map analysis scores for topographic map use tests by groups of students with different subject combinations; count per group in brackets. (Geography group n = 117, non-Geography group n = 71)

In order to visually compare the map reading and map analysis performance of the different groups, the map analysis scores were upscaled to an equivalent mark out of 10 and both scores are plotted in Figure 4.3. The Geography only group showed the greatest discrepancy between scores, with a mean of 8.4 (84%) for map reading but only 2.0 (20%) for map analysis. In contrast, the Geography Mathematics students fared relatively better with a shortfall of only 4.3 (43%) between map reading and map analysis scores.

4.4.3 Time taken to complete the map reading and map analysis test

Figure 4.4 shows a comparison between mean test completion times, scores for students with Geography and those without are included. Time was recorded at the start and end of the test with no differentiation between map reading and map analysis. When examining the overall time taken, there is a clear distinction between the Geography and non-Geography groups. The mean time for the former group was shortest, on average completing the test in 25.1 minutes. Those taking all three pre-requisite school subjects completed in the fastest average time of 24.9 minutes. Those who had not taken Geography took 26.9 minutes on average, 1.78 minutes longer than the Geography group. While acknowledging differences in student working styles, ranging from working impulsively (fast and inaccurately) to working reflectively (slowly and accurately) (Kagan, 1964a; 1964b), the data from this investigation suggest that those who had no former schooling in Geography (apart from the two hour pre-test intervention) took longer to complete the map use test.

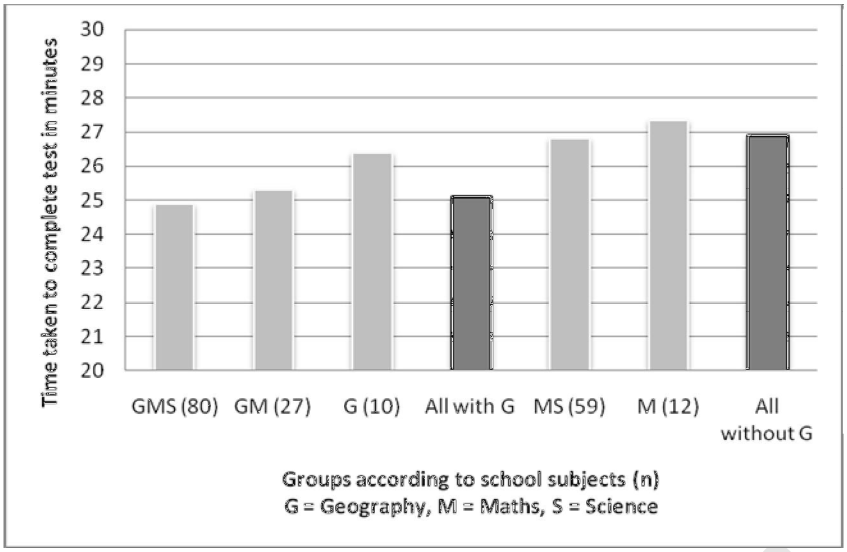


Figure 4.4 Time taken by groups of students with different subject combinations to complete a topographic map reading and map analysis test; count per group in brackets. (Geography group n = 117, non-Geography group n = 71)

4.5 CONCLUSION

The results show that taking both Geography and Mathematics at school level has a positive influence on topographic map skills. Some of the assumptions underlying of the hypothesis (listed in 4.2.3) proved, however, only partially correct. Students who took Geography at school gained higher scores for map reading and completed the overall map use test faster than those who had not taken Geography. However, the geography learners displayed limited ability to analyse the spatial information on maps, proving assumption a) only partially correct. Students with Grade 12 Mathematics (but not Geography), rather than being poor map readers, the first premise of assumption b), can read a topographic map almost as well as the students of Geography following only minimal intervention. Although their map analysis scores were unexpectedly low, the Mathematics group still performed better than those without Mathematics suggesting that the second premise of assumption b) is correct. As anticipated in assumption c), those who performed best at map reading and analysis were the group with both Geography and Mathematics, outperforming even the group with Geography, Mathematics and Science. For the small group (10 out of 188) who had taken only Geography and neither Mathematics nor Science, their map reading score was the highest while their map analysis score was the lowest. This seems to suggest that, in Geography classrooms, too little attention is paid to teaching calculation (mathematics instruction) to ensure efficient topographic map use. It is hoped that in the future, with the emphasis on ‘mathematics for all’ in the new curriculum model for South African education (DoE, 2005), map analysis skills may also be improved.

CHAPTER 5
MAP ANALYSIS SKILLS FOR THE WORKPLACE

"The boundary of ignorance is not very far away,
it seems sensible to stake it out before we try to cross it."

Gould, 1973: 182

5.1 INTRODUCTION

5.1.1 Background

The results of the *MapTrix* survey, discussed in Chapter Three, indicated that, while the use of the self-instruction methodology improved map reading ability among learners and improved the attitude of educators towards teaching map use, the programme did not address the higher order skill of map analysis. The exploratory investigation with first year geography students at university, reported in Chapter Four, indicates that both Geography and Mathematics instruction are necessary for improving map analysis skills. The map analysis tasks used in the intervention procedure (Figure 4.1) were derived from close scrutiny of the pre-1994 geography syllabus still applicable at the time that the investigation was conducted. When the documents for the new senior secondary school curriculum became available (DoE, 2003), the distinction between reading, analysing and interpreting topographic maps was not made clear, nor was a hierarchy of map analysis skills indicated (as discussed in Chapter Two).

Apart from identifying specific tasks that can be categorised as map analysis, it is also necessary to consider the place of map analysis within the broader context of spatial skills. The term *spatial literacy*, perhaps considered an evolving concept, was used in the new geography education policy documents (DoE, 2003). More recently the term *spatial thinking* has gained ground internationally (NRC, 2006). In an attempt to develop a working definition, applicable to Geography at secondary school level, for a term to encapsulate spatial skills, the OBE concept of capability or *ability to* *perform* (Wolf, 1995, and more recently, Osmond, 2004) suggested the use of the term *spatial competence.*

Because the focus of this research is on the outcome of education and training in the use of spatial information, it is important to ascertain what competencies industry representatives expect from learners emerging from formal secondary education. So much has changed in the spatial information industry that guidelines from existing syllabuses, curricula and school textbooks on the topic of map use, need to be reassessed. To find out exactly which map analysis tasks are important in the world outside the geography classroom, the assistance of people whose daily line function depends on the use of spatial information was sought.

To identify the nature, extent and context of the spatial analysis tasks in which those who have taken Geography at school should be competent, two focus questions emerged:

a) What map analysis skills do potential employers anticipate from school-leavers who have studied Geography to Grade 12?
b) What is spatial competence; how can it be defined?

The objective of this chapter is to answer these questions.

5.1.2 Distinguishing map analysis from map reading and map interpretation

The valuable and extensive work of Boardman (1983 to 1996) and others in developing graphicacy has already been acknowledged but these studies were not specifically aimed at designing learning material to meet self-instruction requirements. In order to develop learning material for spatial competence it becomes necessary to specify each learning unit and then accommodate each one within a hierarchy that leads the learner from simple to more complicated tasks.

To illustrate the difference between reading, analysis and interpretation, a comparison between studying maps and studying poems from a recently published South African Geography Grade 10 textbook is instructive (Table 5.1). Given the principles embodied in Table 5.1, it is clear that map analysis tasks rely on the learner's ability to recognise different elements of patterns such as points, lines and areas, and identify their shapes by naming them. Further they should be able to measure aspects such as line length, distance between points and area of different shapes, as well as being able to compare such measurements. Because topographic maps also represent a three dimensional landscape in a two dimensional plane, learners must also be able to visualise the landscape using elevation measurements and height clues. Furthermore, in South Africa (among few other places), map analysis involves the use of a geographic co-ordinate reference grid to locate places, which in turn requires an understanding of angles and their measurement in degrees, minutes and seconds. The range of tasks and their varying levels of complexity are considerable.

Table 5.1 Maps and poems in relation to the concepts: reading, analysis and interpretation

Maps	Poems
Reading maps means the ability to identify, distinguish between and comprehend map symbols	**Reading** poems means the ability to identify letters of the alphabet, recognise words and understand their meaning
Analysing maps means identifying patterns, measuring and calculating: e.g. recognising colours and shapes, using scale to measure distances between places, calculating area and gradient	**Analysing** poems means looking for patterns, measuring and calculating: e.g. recognising repeated words or their meanings, measuring the length of lines and the number of lines per verse, calculating rhythm and rhyme patterns
Interpreting the meaning of maps is easier if we have more than one source of information and if we know when and why the map was made, who made it and for whom it was made.	**Interpreting** the meaning of poems is easier if we know more about the ideas the poets were dealing with, when and why they were writing, who they were and for whom they were writing.

(Adapted from Beets *et al.*, 2005a: 14 and 15)

In order to investigate map skills requirements in the context of the world of work, using various sources of spatial information, a proposed hierarchy of map analysis skills was developed and its validity tested with a focus group of spatial information users by means of a questionnaire (Appendix 5.1). The responses of the local work-place focus group are then compared with the responses of a second, international focus group comprising eminent educators who specialise in developing the spatial skills of young people.

5.2 MATERIALS AND METHODS

5.2.1 Designing the questionnaire

Task analysis, a basic computer based training (CBT) principle (Alexander and Blanchard, 1985), may be applied to this problem learning area in geography education at secondary schools in South Africa in the context of this study. Logically, then, a clear progression from basic map reading through map analysis to map interpretation of spatial information is required if learners are to become competent in the use of maps and other forms of spatial information. Figure 5.1, to be read from the top down, illustrates a skills hierarchy, based on the South African matriculation geography syllabus (still in use when the research into map reading was initiated; Innes, 1998). Map interpretation in the sense in which the term is used in this thesis was not clearly defined at the time but was assumed to be an extension of both the reading and analysis of spatial information. *MapTrix* (Innes, 2000) addresses Task level 1. An advanced map analysis programme needs to address tasks at levels 2, 3 and 4. The skill structure in Figure 5.1 formed the basis of the questionnaire (Appendix 5.1).

TASK LEVEL 4
GRADIENT CALCULATION

ò
depends on the capability of
ò

TASK LEVEL 3
MEASURING DISTANCE; ASSESSING HEIGHT
(to be taught in either order)

ò
which depend on the capability of
ò

TASK LEVEL 2
LOCATING POSITION; DESCRIBING DIRECTION; MEASURING BEARING
(to be taught in any order)

ò
which depend on the capability of
ò

TASK LEVEL 1
READING MAP SYMBOLS
THEIR IDENTIFICATION, RECOGNITION AND COMPREHENSION
(a starting point)

Figure 5.1 Task analysis, working backwards from the desired outcome

Another way to arrange the map use skills into a hierarchical order is to conduct a task analysis on each task individually (Gagné and Briggs, 1974). The example in Table 5.2 illustrates the analyses of the task of map orientation, which is the first map use task listed in the new Grade 10 Work Schedule (DoE, 2008b: 35).

Prerequisite skills are identified first (Table 5.2a) and stated as tasks for further analysis (Table 5.2b and 5.2c). New knowledge that must be learned in order to perform the task is identified; this constitutes the lesson component of the instructional unit. The task itself is carefully described and then the level of performance and the equipment required are identified. These are then written up as the technique(s) required to perform the task (with examples) and the learning activities or exercises which learners use to demonstrate whether or not they are competent at performing the task. The identified prior knowledge items become task units themselves, to be taught at a lower grade. In the example in Table 5.2, two units of prior learning are identified and expanded: map reading (5.2b) and using a compass to find north (5.2c). These lower skill levels or pre-requisite tasks need be have been dealt with before learners attempt map analysis.

Table 5.2 a, b and c Analysing the task of orientating a map

a. Orientate a map	*Task analysis questions*	
	What prior knowledge is required?	1. Read a map 2. Use a compass to find north
	What new knowledge must be learned?	North convention on maps
	What specific task(s) must the learner be able to do?	Rotate (turn) local map sheet to match position of features on the ground. Use direction indicator on map to identify north
	at what skill level?	within 5 minutes, direction arrow on map to match compass arrow exactly
	using what equipment?	topographic map, compass

b. Read a map	*Task analysis questions*	
	What prior knowledge is required?	Read and understand the key and words used on the map
	What new knowledge must be learned?	Relate key and words to geographic concepts represented, distinguish between natural and constructed features etc
	What specific task(s) must the learner be able to do?	Recognise that map symbols represent features, know names of features, identify symbols, differentiate between symbols, recognise symbols, match symbols to features, answer questions about information on the map
	at what skill level?	within a reasonable time and with a high degree of accuracy
	using what equipment?	local topographic map

c. Use a compass to find north	*Task analysis questions*	
	What prior knowledge is required?	Cardinal points
	What new knowledge must be learned?	Demonstrate an understanding of the mechanism of a compass
	What specific task(s) must the learner be able to do?	Place compass of a flat surface away from metal objects, wait for it to settle, turn the compass housing until N lies directly above the marked end of the magnetised needle, identify landmarks in a northerly direction
	at what skill level?	within 2 minutes and with a high degree of accuracy
	using what equipment?	magnetic compass

Once a task has been described and the pre-requisite tasks identified, then higher order skills are identified for which the new task becomes, in turn, a prerequisite. With reference to the task of map orientation in the example in Table 5.2, a higher level skill is the accurate orientation of a map to true north by calculating current magnetic declination. Such a unit should be taught later, possibly in a higher grade.

Based on the skills listed in the former syllabus documents (e.g. Transvaal Education Department, 1983) together with the author's experience of teaching map skills courses for adults in the workplace (Innes and Engel, 2001a and 2001b) a proposed outline for a map analysis learning programme structure, based on eleven different tasks, was developed. An attempt was also made to distinguish between the levels of difficulty or complexity of each task (see Table 5.4).

Regular users of spatial information were needed to help provide answers to a number of questions, with a view to guiding education and training in this area:

- Which spatial information products were used most often in the workplace?
- Which tasks were regularly performed using spatial information in the workplace and to what level of accuracy?
- How difficult were the tasks to perform and which ones should school leavers be able to perform?
- What was understood by the term *spatial literacy*?

To obtain answers to these questions, a four-part questionnaire was developed requiring participants to fill in a series of code boxes. For the first two sections, possible options were listed with open ended questions for additional information. Participants were asked to code their responses as follows: A = Very often (everyday or alternate day), B = Quite often (once or twice a week), C = Seldom (one or twice a month). They were also requested to supply a small amount of biographical information (see Appendix 5.1).

In respect of this aspect of the study, a postal questionnaire survey was initially considered notwithstanding the difficulties encountered during the survey reported in Chapter Three. A user-needs survey had been conducted by the national mapping organisation (NMO) and respondent details were available (Spencer-White, 1999). However, as reported below (section 5.2.2), an opportunistic population sample (Ebdon, 1985) in the form of a focus group became available. This made it possible to conduct a participatory research exercise (Bless and Higson-Smith, 1995) in which the researcher acquired the information necessary for the learning programme structure and the participants benefited from information that assisted in their own understanding of the training needs of their entry level staff.

5.2.2 Population sample – work-place focus group

The author was invited to make a presentation at a meeting of the Western Cape GIS User Group (CaGIS). The topic of the presentation was the MapAware Project and the work being undertaken by the NMO to promote spatial competence (Innes and Engel, 2001b). This was of special interest to the group members who were seeking ways to improve the skills of their entry-level staff. The group met regularly at that time to discuss issues related to various GIS applications and the spatial information industry in general. CaGIS later formed the core of the Western Cape branch of the Geo-Information Society of South Africa (GISSA) (www.gissa.co.za). This invitation was recognised as a unique opportunity to interact with a focus group of spatial information users and the author agreed to make the presentation on condition that the members present at the meeting agreed to participate in the survey.

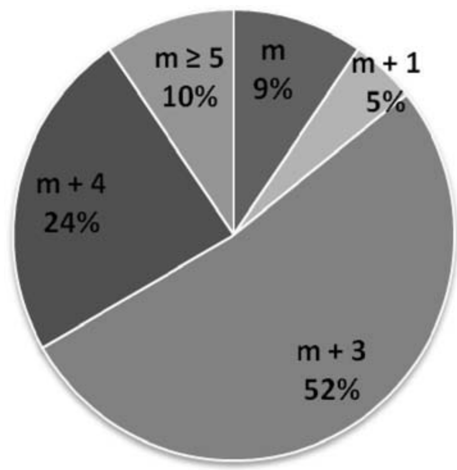


Figure 5.2 Years of study following matriculation (m) of the GIS focus group members (e.g. m + 3 = matriculation plus three years of further study)

In order to evaluate whether the 21 members of the focus group had specialised training in GIS, they were asked to indicate the number of years of study beyond formal schooling that they had undertaken. The results in Figure 5.2 show that only 14% of the sample had less than three years tertiary training, the balance had three or more years of training. As might be expected from staff with a relatively high level of training, 48% were in supervisory or management positions, making them suitable candidates to consult regarding entry-level skills expectations.

A breakdown of the employment sectors represented by the respondents shows that the majority of the users were employed in the public sector, responsible for the provision of services (Figure 5.3). Those serving in local civic authorities were the largest group, the second largest worked in the Surveyor-General's (SG's) Office in Cape Town. One small group was employed by a private GIS company and the remaining members were employed by the Western Cape Provincial Administration Department and by South Africa's Electricity Supply Commission (Eskom). The group thus represents a variety of spatial information users at a relatively senior professional level.

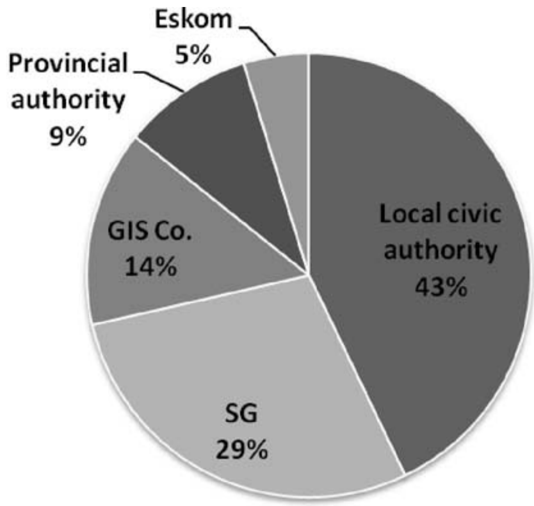


Figure 5.3 Employment sectors of GIS focus group members

In a plenary session, each section of the questionnaire (Appendix 5.1) was described. A group discussion was led regarding the different sources of spatial information they used and the tasks they performed. At the end of this session, each participant was asked to complete the questionnaire. Their responses were linked to their regularity of engagement with the products and/or tasks. Although individual interviews were not conducted, queries were addressed by the researcher as they arose from the group in line with Ebdon's (1985) guidelines for researcher-administered questionnaires. Completed questionnaires were collected at the end of the meeting.

5.3 RESULTS

5.3.1 Spatial information products

A review of the spatial information products most commonly used in the GIS workplace was conducted (Figure 5.4). Structured responses were required to six spatial information products selected from those assumed to be in wide use. A partially open-ended response to thematic maps was requested and then participants were asked to indicate any other types and/or formats of spatial information that they use regularly. The products listed include the 1:50 000 topographic map (base map of the national mapping series, produced by the NMO), aerial photographs, 1:10 000 orthophoto maps (both available from the NMO and other sources), road maps, national or regional maps (various suppliers), and property diagrams[1] which are available from the SG Offices. In order to establish guidelines for suitable learner support material, participants were asked to indicate how often they used each product and whether the spatial products they used most often are in the paper or digital format.

Weighting of their responses was achieved by asking participants to indicate the types and formats of spatial information that they used on a regular basis. To quantify regular use, they were asked to distinguish between products used: A *very often* (every day or alternate day), B *quite often* (once or twice a week) and C *seldom* (once or twice a month). For products used less than once a month the respondents were asked to leave the code boxes empty. Responses were weighted as follows: *Very often* (3), *quite often* (2) and *seldom* (1). Weighted scores for each product were compared to identify those with which a prospective employee should be familiar.

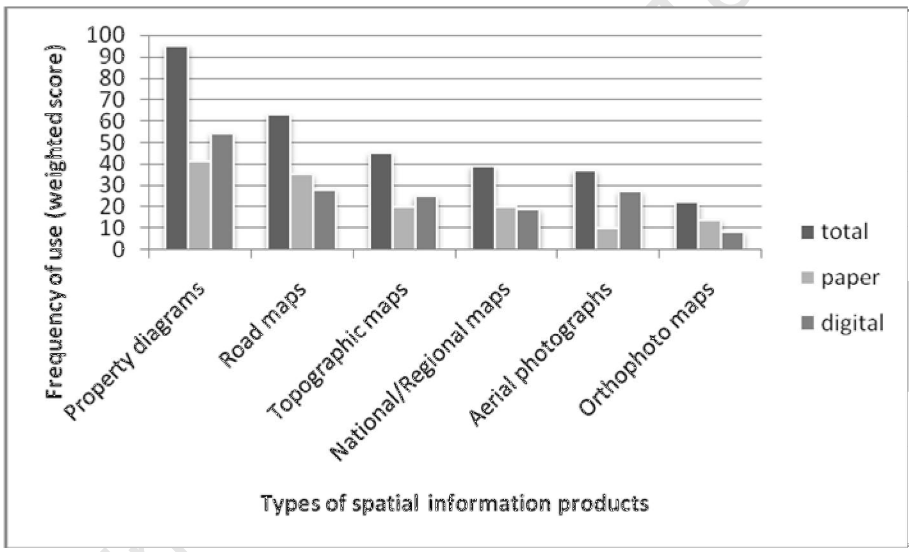


Figure 5.4 Frequency of use of different spatial information products (and their formats)

Figure 5.4 represents the total weighted scores for the frequency of use of spatial information products (in paper based and digital formats) by the participants. It reveals that cadastral data, in the form of property diagrams, are used most often by the respondents. Although this result could be expected given the employment profile of the participants, the importance of including reference to cadastral data in a spatial learning programme is obvious. The spatial information products ranked second are road maps, again not prescribed learning materials. Topographic maps, prescribed material for the matriculation geography practical examination ranked third on the list of products

[1] Property diagrams accurately identify cadastral boundaries including the co-ordinates and altitude of each node and the angles and lengths of each line forming the property boundary. Original cadastral boundaries and registration numbers are indicated on the 1:50 000 topographic map of South Africa. Sub-divisions can only be registered when accompanied by a property diagram. Incidentally, property diagrams are not currently prescribed as learning materials.

used most regularly by the participants, followed by national/regional maps and aerial photographs. Orthophoto maps, although prescribed material included in the matriculation examination, are used least often.

All products listed are available in South Africa in paper and digital formats but use by respondents varied according to product type. Property diagrams and aerial photographs were clearly used more often in the digital format; there was also a slightly higher use of digital topographic data. Paper road maps and orthophoto maps were used more often than digital versions and there was an almost even balance of both formats used for national and regional maps. Overall it is clear that candidates at secondary education level should be prepared for the use of both paper and digital formats of spatial information.

Just over half the candidates (11/21) indicated that they used various thematic maps including urban land use zones, electricity consumption and various population indicators. These products were used for comparative and/or interpretive purposes and correspond with maps recommended for use in geography teaching, reinforcing their inclusion in learner support materials for map use. In most cases, both paper and digital thematic maps were used with the same degree of regularity although three participants indicated that while they seldom used such maps, they used them only in the digital format.

5.3.2 Spatial information task analysis - frequency

In the light of experience gained while offering industry related training to adult map users at MapAware workshops (Innes and Engel, 2001), eleven specific tasks requiring the use of spatial information were identified. Using the skills hierarchy illustrated in Figure 5.1 these were ranked and then differentiated into sub-tasks of successive levels of perceived difficulty (Appendix 5.1 and Table 5.4). Before estimating the difficulty of each task, participants were asked to estimate the frequency at which they performed these tasks by filling the boxes beside each sub-task with codes A, B or C depending on the regularity with which they were performed.

Tasks 1 to 9 require some level of mathematical competence and are directly related to answering focus question a) (at the end of 5.1.1). Tasks 10 and 11 are considered higher level interpretive tasks and were included to help answer focus question b). They have been eliminated from the lists of spatial analysis tasks that follow. As with the product evaluation, once participants had indicated how regularly they performed each analytical sub-task, they were weighted as follows: those performed *very often* (3), *quite often* (2) and *seldom* (1).

Table 5.3 Spatial analysis tasks ranked according to frequency of performance from most to least often

Task number	Spatial analysis task	Incidence value	Frequency ranking
9	Identifying boundaries	44	9
1	Locating features	33	8
3	Calculating distance	27	6
4	Describing location	27	7
7	Calculating area	22	5
2	Describing direction/bearing	15	3
8	Identifying landforms	15	4
5	Estimating altitude	11	2
6	Calculating/recording gradient	8	1

The responses were totalled per task and the tasks were then ranked based on the incidence of performance in the workplace (Table 5.3). Participants were asked to list other tasks that they performed. Only five added tasks to the list which included: digital data capture, digital terrain modelling, maintaining spatial information, creating thematic maps and defining statistics for specific geographic areas. It was later realised that these were tasks typical of GIS in particular and that they should be included in a future instruction programme so that learners use maps for practical and relevant investigations (Kohn, 1982) as opposed to 'doing mapwork'.

When comparing the tasks as ranked by the GIS users with those usually emphasised in South African geography textbooks, significant differences occur. Gradient calculation is often regarded as a high priority task expected of matriculants with Geography, however, the ranking in Table 5.3 shows that it is the task least often performed by the participants. Boundary identification is the task most often performed in the work place yet, by contrast, seldom appears in teaching texts or examinations. When identifying landforms, participants frequently named them rather than profiling them. This is in strong contrast to the stress placed on drawing cross-sections, a classic mapwork task in the classroom.

5.3.3 Spatial information task analysis – difficulty ranking

Participants were asked to rank all sub-tasks in four classes from very easy, easy, moderately difficult to very difficult. Clear guidelines were offered for their classification, including the school grade at which they felt these tasks should be mastered and a description of the spatial literacy competence of learners able to perform such tasks. The number of times that each sub-task was placed in a class was totalled, and then the classes were weighted: *very easy* (1), *easy* (2), *moderate* *difficulty* (3) and *very difficult* (4). The weighted scores were then totalled per task and then a ranked value was assigned to each task from the easiest to the most difficult (Table 5.4).

Table 5.4 Spatial analysis and interpretation tasks listed according to assumed difficulty plus the difficulty score and ranking of the GIS focus group

Task Code	Spatial analysis tasks divided into sub-tasks based on perceived difficulty levels	Score	Rank
1a	Locating features using an alpha-numeric grid	21	31
1b	Locating features using latitude and longitude	35	21
1c	Locating features using survey co-ordinates	54	4
2a	Describing direction/bearing using 8 cardinal points	37	19
2b	Describing direction/bearing correct to approx. 2°	43	14
2c	Describing direction/bearing correct to 1° or less	52	9
3a	Calculating distance correct to approximately 10 m	26	28
3b	Calculating distance correct to approximately 1 m	33	24
3c	Calculating distance correct to < 1 m	42	16
4a	Describing location using an alpha-numeric grid	26	28
4b	Describing location using latitude and longitude	35	21
4c	Describing location using survey co-ordinates	53	7
5a	Estimating altitude correct to approximately 10 m	34	23
5b	Estimating altitude correct to approximately 1 m	43	14
5c	Estimating altitude correct to < 1 m	54	4
6a	Calculating/recording gradient as a ratio (height: distance)	52	9
6b	Calculating/recording gradient as an angle of slope	51	11
6c	Calculating/recording gradient as a trigonometric function	53	7
7a	Calculating area correct to 1 ha	33	24
7b	Calculating area correct to 10 m^2	37	19
7c	Calculating area correct to 1 m^2 or less	54	4
8a	Identifying landforms by naming features	32	26
8b	Identifying landforms by describing slope form/aspect	49	12
8c	Identifying landforms by generating profiles	59	1
9a	Identifying regional/district boundaries	23	30
9b	Identifying boundaries of land use zones	31	27
9c	Identifying property boundaries	40	17
10a	Visualising terrain, integrating natural and constructed landscape	48	13
10b	Visualising terrain, integrating landscape plus changes over time	59	1
11a	Reproducing features by sketching/copying at the same scale	40	17
11b	Reproducing features by sketching/copying at larger or smaller scales	56	3

The assumption of increased difficulty from sub-task a to sub-task c within each task was confirmed by the participants. Colour shading has been used to emphasis the successively higher difficulty scores awarded for each sub-task from a to c. The only task where the progression is less apparent is Task 6, gradient calculation. All sub-task scores are high, suggesting that each variation of the gradient task proved very difficult. This information is valuable in setting exercises at successively higher grades but does not help to identify a skills hierarchy per task. The same can be said of the difficulty ranking in the last column of Table 5.4 which compares all sub-tasks against each other. However, neither contributes to producing a task lesson hierarchy. What proves more valuable is totalling the difficulty score per task. The resulting ranking of tasks according to difficulty is illustrated in Table 5.5.

Table 5.5 Spatial analysis tasks ranked by GIS users from easiest to most difficult

Task number	Spatial analysis task	Difficulty score	Difficulty ranking
9	Identifying boundaries	94	1
3	Calculating distance	101	2
1	Locating features	110	3
4	Describing location	114	4
7	Calculating area	124	5
5	Estimating altitude	131	6
2	Describing direction/bearing	132	7
8	Identifying landforms	140	8
6	Calculating/recording gradient	156	9

While the review of spatial information products and performance of spatial task frequency by the participants provides valuable insight into the materials and lesson content that should be included in the proposed self-instruction programme; what proves to be much more illuminating is their opinion of the difficulty level of each task.

5.3.4 Identifying an appropriate skills hierarchy for instruction in spatial analysis skills

Two important factors were taken into consideration when identifying the sequence and scope of the spatial analysis skills to be included in the prototype self-instruction programme:

- Tasks that are commonly performed, familiarity with which would be advantageous to school leavers,
- A skills hierarchy that could be followed in order to assist learners to develop the requisite geographical, cartographical and mathematical concepts sequentially, gaining confidence at each level of complexity before progressing further and tackling more difficult tasks.

The design had to make provision for the fact that the self-instruction map analysis programme could later be the foundation for a self-instruction programme for the interpretation of spatial information.

When comparing Tables 5.3 and 5.5 it appears that tasks performed most often might be considered the easiest (Task 1 - identifying boundaries) and those performed less often the most difficult (Task 6 - gradient calculation). Tasks 1, 3 and 4 were often performed and all fell between 2 and 4 on the difficulty ranking but not in the same order. Likewise tasks 2, 5 and 8 were seldom undertaken and appeared in a similar difficulty ranking. However, other trends emerged that suggested that tasks could be grouped according to factors independent of difficulty levels or how often they are performed. Further examination of the tasks in relation to developing the necessary lesson text per task (in keeping with task analysis described in Table 5.2) reveals that locating features (Task 1) and describing location (Task 4) required the same content knowledge so it was decided to group them as one task requiring the same instruction text and illustrations.

Closer inspection of the difficulty ranking and the equipment required for the sub-tasks of Task 2 revealed that, while describing direction was considered relatively easy, measuring bearing accurately (clearly a mathematical skill) was considered more difficult. It was therefore decided to differentiate Task 2 into two tasks (see Table 5.6). Although profiles are not often constructed in the workplace (according to this focus group), this task has been retained in the programme as preparation for a high level competence required for the geographic interpretation of landscape (such as distinguishing between slope forms or identifying microclimate zones).

Table 5.6 Final hierarchy for spatial analysis skills for prototype self-instruction programme

Difficulty level	Spatial analysis skills requiring mathematical competence
1	Identifying boundaries
	Describing direction
2	Using or describing absolute location (using geographic co-ordinates)
	Measuring bearing
3	Assessing altitude or height
	Measuring distance and calculating area
4	Calculating gradients
	Drawing or interpreting profiles (to identify landforms)

5.3.5 Proposed definition of spatial literacy

Once they had engaged with the various tasks and considered the differences in their difficulty levels, focus group members were requested to review a proposed definition of spatial literacy (Box 5.1) and approve, reject or amend it.

Box 5.1
Proposed definition of spatial literacy

Spatial literacy is the ability to

- read with understanding spatial information about the natural and constructed environment from various sources including maps and aerial photographs in paper and digital formats,
- analyse that information and present results mathematically and/or verbally,
- visualise the landscape from the interpretation of spatial information and
- present selected information graphically as required.

None of the 21 participants rejected the statement, 19 approved it and two proposed amendments. One suggested that the list of sources should include satellite imagery and another that landscape visualisation should include proposed changes over time. Both would elevate the level of competence required to attain spatial literacy and indicate that perhaps a broader definition should be developed, one which differentiates between different levels of competence.

5.4 REVIEW OF RESULTS BY SECOND FOCUS GROUP

The results of the GIS user group survey leads to a significant re-evaluation of the skills hierarchy and scope that had initially been identified from earlier syllabus requirements and during map literacy training workshops conducted with adults already in the workplace (Innes and Engel, 2001). The resulting hierarchy of skills in Table 5.6 was used in an attempt to collaborate with teachers in the development of the exercises for the self-instruction programme. This exploratory investigation is reported in Chapter Six.

A second opportunity to explore the map skills hierarchy and definition of spatial literacy presented itself when the researcher was asked to help make local arrangements for members of the International Cartographic Association's (ICA) Commission on Cartography and Children (CCC) for their meeting in Cape Town in September 2003.

The same questionnaire that was used with the spatial information practitioners was presented to this second small focus group with a high degree of interest in children and cartography. A small number of local stakeholders in improving map skills were invited to attend the meeting including educational publishers, teachers and staff members involved in the MapAware Project of the NMO. Twelve questionnaires were returned. Some sections were omitted by foreign participants who appeared to find the language a barrier but all responded to the section on a proposed definition for spatial competence.

The two groups ranked the tasks slightly differently with regard to frequency of performance with the GIS focus group emphasising more practical issues related to property boundaries and the CCC focus group more concerned with landform identification. Members of both the GIS and the CCC groups listed additional sub-tasks that were later incorporated into the learning programme where relevant.

It was in defining spatial competence that the contribution of the CCC group was most significant. When the definition in Box 5.1 that was almost unanimously approved by the first focus group was presented to the CCC focus group (incorporating the GIS group's suggestions) only five members approved the definition without reservation while seven approved it with amendments. Their amendments generally fell into four categories: improved wording, loss of distinction between analysis and interpretation, inclusion of spatial orientation in reality and inclusion of three-dimensional representations (such as models and profiles). Mention was made of an awareness of maps as selective, generalised representations as well as the inclusion of landscape feature explanation (based on map interpretation).

One highly experienced respondent suggested changing the definitional term to *cartographic competence*. After careful consideration it has been decided not to act on this suggestion. Cartographic competence implies a high level of proficiency in map production, a skill beyond the realm of the school environment. The term *spatial* with reference to mapped information has come into current use, both within the cartographic community and the rapidly growing spatial location industry. The term is also now used in the South African curriculum documents, notably in the opening definition: 'Geography is a science that studies physical and human processes and spatial patterns on Earth in an integrated way over space and time' (DoE, 2003, 9). However, with the emphasis on displaying competence in the outcomes based education (OBE) model adopted by South Africa, it was decided to use the term *spatial competence* rather than *spatial literacy*. The definition to be used for developing a comprehensive spatial competence skills hierarchy is laid out in Box 5.2.

Box 5.2
Definition of spatial competence

Spatial competence is the ability to

- orientate oneself, find places and follow routes using appropriate landmarks and directional information (with and/or without maps)
- recognise a map as a generalised representation of the world transformed, reduced and projected onto a two dimensional surface which usually has a location reference system
- read and understand spatial information about natural and constructed environments from various two and three dimensional representations including but not limited to paper and digital maps, photographic and other images
- analyse spatial information at various scales from point, line and area data and present results in oral, text, graphic or numeric formats
- interpret spatial information and explain spatial patterns in a geographic context
- visualise landscape (including changes over time) from spatial information
- draw maps, representing selected spatial information in graphic format

The constructive criticism of the CCC focus group is gratefully acknowledged and suggestions have been thoroughly considered and incorporated where possible. One exception is the lack of distinction between analysis and interpretation. In order to develop learning material for spatial competence it is necessary to specify each learning unit and then accommodate each one within a hierarchy that leads the learner from simple to more complicated tasks.

5.5 DISCUSSION AND CONCLUSION

The findings of the GIS user group survey led to a significant re-evaluation of the skills hierarchy and scope that was initially proposed (Figure 5.1) as well as the skills identified during adult training (Table 5.1). It has become clear that learners should be exposed to property diagrams and should also be able to describe the patterns associated with property boundaries (cadastral information) depicted on topographic maps. When evaluating the mathematical complexity of the spatial analysis tasks that had been identified, it was decided to change the ranking to represent the sequence of the mathematical tasks as well as their perceived difficulty level. Table 5.6 illustrates the skill ranking that was adopted as the framework for the development of spatial analysis lessons and exercises for the prototype map analysis programme. The first focus question has thus been answered by identifying the map analysis skills that potential employers might reasonably expect from school leavers who have completed Grade 12 Geography.

The definition of spatial competence (Box 5.2), developed with the assistance of GIS users and map use teaching experts, answers the second focus question of the chapter and positions map analysis skills within a broader context. There is a clear mismatch between what is expected in the work place and what is currently being taught in South African geography classrooms. As GIS technology makes it possible to perform spatial analysis tasks more systematically and often with unprecedented levels of accuracy, so school leavers need to be taught differently. They need to use GIS technology to view, read, analyse and interpret spatial data and to learn the basics of gathering that data using GPS. It is a credit to the developers of the new curriculum that they have recognised this need and have included the necessary topics in the NCS for Geography (DoE, 2003) but for policy to be effective, it must be turned into praxis.

If educators are to play their part in improving spatial competence they must be offered adequate training and resources. In relation to map use, teaching artistic skills as in the past must give way to developing mathematical skills in the present as we prepare school leavers to analyse and solve the spatial aspects of sustainability problems of the future. It is hoped that a self-instruction programme for map analysis, built around the existing *MapTrix* materials and including the teaching of the Mathematics required by map users will be useful in attaining this goal.

It is not assumed that this limited sample is representative of all employers in the spatial information industry nor all users of spatial information nor experts in teaching spatial competence but their participation has thrown valuable light on the path that educators should be preparing school leavers to follow. The following chapter investigates the preparedness of South African teachers of Geography to take their learners down that path.

CHAPTER 6

GEOGRAPHY TEACHERS' ABILITY TO MEET SPATIAL LEARNING NEEDS

Society and environment '...are complex, difficult, and delicate systems. In dealing with these systems, we must use much more of what we know, and we must start to know more very soon'.

Kaplan, 1973: 78

6.1 INTRODUCTION

It has been established in previous chapters that the NCS for Geography provides opportunities for enhancing spatial competence within the provisions of South Africa's National Qualifications Framework (NQF) (DoE, 2005). In Chapter Five, the map analysis skills required of school leavers entering the workplace were identified. This chapter discusses the ability of geography teachers to meet their spatial learning needs. Two questions will be addressed:

a) Do geography teachers have the resources they need to teach map skills?
b) Have geography teachers received adequate training for the task?

6.1.1 Assessment of spatial skills at school

In the period leading up to 1994, a multiplicity of practical geography examination papers was set for the Senior Certificate as discussed in Chapter One (1.5.3). Different examining bodies for the education of different racial groups existed in each of the four provinces. These groups were historically referred to, and formally ratified under apartheid legislation, by colour: Whites, Coloureds and Indians. A national examining body, the Department of Education and Training (DET) assessed the education of Black learners. Generally, White teachers followed the guidelines provided by the relevant examination papers and the general standard of map use performance was regarded as acceptable (Liebenberg, 1998). Questions explored map reading, analysis and interpretation, although many focused on mapwork for its own sake rather than on using a map to examine the landscape represented. Examples of this were measuring distances from A to B as opposed to distances between features of the landscape and the focus on the information shown around the margin of the map such as calculating the change in annual magnetic declination change. Gradient calculation was a typical example testing analytical skills. At the map interpretation level, questions might include the influence of slope aspect on temperature and the impact of landscape on urban morphology. The Coloured and Indian provincial education departments maintained similar examination protocols for their practical geography examination papers as the White provincial education departments. All three racially divided examination bodies in the four provinces offered open-ended medium and short answer questions at the higher, standard and lower grade. Learners had the option to be taught and examined in their mother tongue, being either English or Afrikaans.

Burton (1990) showed that there was a significant disparity between the examination results for the mapwork and theory papers for Geography, across all examining bodies, with the mapwork examination scores being consistently lower. This was particularly noticeable for the Black matriculants of the DET who were examined in either English or Afrikaans and not in their mother tongue (which could be any one of nine traditional African languages). A problem of assessing second language learners' comprehension, which may have relevance to map reading, is the problem of a measurement device that requires text reading and writing skills to assess map reading skills. Low proficiency readers and writers may appear to have limited comprehension of maps merely because they cannot express themselves adequately in writing. In the same way, the examination candidate may misinterpret questions or may not have the vocabulary to answer them adequately (Block and Rollnick, 2002). It may be for this reason that the structure of the practical geography examination paper of the DET consisted exclusively of multiple choice questions with one word answers offered with only two distracters. Despite the fact that this was clearly an easier option than that used by the other examining authorities, devaluing the measurement of spatial competence skills of Black learners, their mapwork examination results were poorer than those of other groups (Burton, 1990: Liebenberg, 1998).

While many senior geography teachers used past examination papers to guide their teaching practice, concern was expressed about the structure and validity of South African map work examinations (Burton, 1990, 1992). There was some debate about whether the examinations reflected the objectives of the syllabus. Learners were being taught to answer the examiners' questions rather than to use maps as a source of information about the environment. A typical example of this preoccupation with what the examiner wanted was the Zap Map Video Series (Eiselen, 1991) in which reference to the examiner is made repeatedly in what is supposed to be learner support material for developing map skills, appearing instead to describe only practical examination tips and techniques.

Following the historical elections of 1994, separate education departments for different population groups fell away. South Africa was divided into nine provinces (see maps in Figures 1.1 and 1.2) and from 1997 to 2007 education departments in each province were tasked to prepare examination papers for each subject that all population groups would write (Le Grange and Beets, 2005). In most cases, the practical examination for Geography retained the more rigorous structure of the former White education departments. The former higher, standard and lower grades were reduced to only two examination levels, higher and standard grade (for the latter, figures are in brackets). The only compulsory question in the geography examination was the mapwork question. The theory paper, worth 320 (240) marks, consisted of eight optional questions worth 80 (60) marks each of which only four had to be answered. The compulsory practical paper worth 80 (60) marks (25 % of the total) had no optional questions and was based on the reading, analysis and interpretation of the 1:50 000 topographic map of South Africa. Vertical aerial photographs at various scales or orthophoto maps at 1:10 000 could also be included. There was no sub-minimum pass mark required for either of the two papers.

In his general review of the real meaning of matriculation results, carried out after the amalgamation of the education departments for learners of different population groups, Faller (2004) found that, across the board, Black teachers accustomed to the former DET style of examination papers reacted negatively to, what they perceived as, a more difficult examination style. Their matriculation candidates performed badly and, as the result of their strong complaints, examination papers in subsequent years appeared to focus on lower order skills. In contrast, teachers from other groups were then concerned that standards were being lowered to accommodate all learners including those previously examined by the DET. While no specific investigation of the geography practical examination papers has come to hand, personal communication with former DET teachers confirmed their negative reaction to the change from using multiple choice answers to short written answers. Faller (2004: 9) notes that, because pass-marks have become part of the incentive system in schools '...there has been a growing tendency to enforce a lower grade entry on learners, or to exclude them from what a school regards as high-risk subjects, simply to increase overall pass rates'. The impact of these trends on the geography examination results that are discussed in Chapter One would be most informative but is unfortunately beyond the scope of this investigation.

As mentioned in Chapter Two (2.5.1), at the end of 2008 all learners of all race groups wrote the National Senior Certificate to assess the effects of the outcomes based education (OBE) policy for

National Education (DoE, 2005). There are no longer different grades of examination papers; all candidates are evaluated at the same level. The results are available, but beyond the scope of this thesis to warrant analysis.

6.1.2 Geography teachers and spatial skills

Fairhurst *et al.* (2003: 82) note that it was the demand for schoolteachers that '...was the mainspring of university geographical education in South Africa until very recent times'. Up until the mid 1990's most geography graduates were still entering the teaching profession. Geography teachers are also trained in colleges of education, many of which were established in the former homelands during the building boom in the 1980's (Hofmeyr and Buckland, 1992). Despite these training opportunities for teachers, the map use performance of school leavers remained poor.

Between 1995 and 2000, Geography was under serious threat as an academic discipline in South Africa with student numbers dropping steadily (Vlok and Zietsman, 2001). A determined effort was made in the geography departments of academic institutions to serve a much broader vocational spectrum; name changes were rife in a bid to 'rebrand' Geography (pers. comm. Prof. M. Meadows). Fairhurst *et al.* (2003) suggest that many occupations taken up by geography graduates are now associated with serving societal needs such as Environmental Science and Environmental Management and that there is a strong demand for geography graduates with training in Geographical Information Systems (GIS) in the rapidly growing geo-spatial industry. Fewer and fewer geography graduates are entering the teaching profession.

The level of spatial competence of geography teachers requires further investigation. If teachers are to help learners address real world issues through the geographic enquiry process (DoE, 2003), they need to be aware of a wider range of spatial information products and how to use them effectively. Geography teaching is in flux. There appears to be little support for geography teachers and little research attention focused on the problems of introducing a new curriculum, radically different from anything used in South Africa before. In the previous decade, Wesso and Parnell (1992: 194) noted that, in South Africa, with few exceptions it was '...particularly unusual for geography education experts with practical experience and broad perspectives on the education system to make the effort to inform others of their knowledge through publications'. In the present decade, with the introduction of GIS into the curriculum, there has been an upsurge in geography education research but it appears to be focussed solely on GIS.

In collaboration with the national mapping organisation (NMO), spatial competence workshops for geography teachers were initiated and were first held in Gauteng and KwaZulu-Natal (Innes and Engel, 2001b) and later in the Western Cape (as discussed in section 6.3). Over time, most provincial education departments have made some use of the teacher training service of the NMO but to varying degrees. An investigation into the impact of this initiative on the spatial competence of school leavers has yet to be conducted (pers. comm. Brian Engel, MapAware Project).

6.1.4 Personal awareness of the need for learning and teaching support materials (LTSM) for map use

Having qualified as a teacher relatively late in life, through correspondence study with the University of South Africa (UNISA), this author was conscious of her lack of experience when facing senior high school classes in her first teaching appointment. When a colleague in the English Department at the same school urged the author to assist with the tutoring of Black teachers registered for an up-grading programme with Vista University, the author initially resisted on the same grounds - inexperience. The colleague's response was "You will be better than nothing!" She went on to explain that the geography teachers were desperate for help, especially with map work. The non-government organisation (NGO) that was sponsoring the tutoring support initiative could find no-one to help them. The experience is recorded in Box 6.1.

Box 6.1
Extract from a speech by the author during the launch of *MapTrix* at the NMO's 80th anniversary celebrations

'Over a period of about 8 years during the 1980's I spent my Saturday mornings at St Antony's Adult Education Centre in Boksburg. I got to know more than two hundred geography teachers whose job, every day of the week, was immeasurably more difficult than mine. They had faced classes disrupted by the violent student protests of the 1970's. They had stood in the front of classrooms where empty desks often meant that pupils had disappeared, perhaps been arrested and detained, or worse. The rest of the class members filled with resentment and rebellion. They were running homes and bringing up their own children on meagre salaries. They were living in tiny homes filled with people, but still had the strength at the end of the day to find a quiet corner to study when their families were asleep. And then to travel, some from 50 and 80 kilometres away, to attend classes on Saturday mornings. As I got to know them, they shared their struggles and difficulties, providing me with a unique window into their classrooms. I developed a great admiration for their courage and determination.

They told me how they were trying to teach without resources in their classrooms, without support from the education authorities, without respect from their pupils. One of their most pressing problems as geography teachers was map work. How do you teach someone to read a map without a map to read? Map use like any other skill requires practice and they had nothing to practice on. I felt a pressing need to supply those teachers with maps. They also needed practice exercises for their geography pupils to improve their map use performance.

My other Monday to Friday teaching subject was English. I had used the Science Research Associates Reading Laboratory which consists of graded comprehension exercises on work cards. If you can improve English comprehension using reading cards, why not improve map comprehension the same way? The idea behind *MapTrix* was born. At that stage I envisaged a programme of exercises that would teach map reading, analysis and interpretation. It was only when I started the research that I realised that I would only be able to tackle one skill level at a time!'

The author's first interaction with geography teachers directly related to the current research was the *MapTrix* survey, conducted during 2002 and reported in Chapter Three. Data gathered from the nationwide postal questionnaire was used to build a profile of teachers working in geography classrooms around the country and to assess their need for resources. The second interaction, on a smaller scale, was the opportunity to collaborate with teachers in the development of exercises required for the proposed map analysis programme while conducting teacher training for the Western Cape Education Department in February 2003. The third interaction was during 2006 while conducting a series of map use workshops for geography teachers, sponsored by an education publishing company, in three different provinces at which an informal survey of computer facilities at schools was conducted.

6.2 GEOGRAPHY TEACHERS' RESOURCE NEEDS SURVEY

6.2.1 Materials and methods

While details of the structure of the *MapTrix* Questionnaire are discussed in Chapter Three, only the details relative to the teachers, gleaned from the first page of the questionnaire (Appendix 3.1), are dealt with in this chapter. A pilot survey was conducted with six geography teachers at schools in and around Cape Town using a draft of the Questionnaire. The selected schools ranged from extremely well-resourced to poorly resourced. Structured face-to-face interviews were conducted with three educators; structured telephone interviews were conducted with the others who had each received the draft questionnaire for close scrutiny beforehand. All participants were asked to comment on the clarity of the questions and their suggestions were later incorporated into the final document. An educator from an under-resourced school advised that questionnaires should be addressed to the school principals, not senior geography teachers. He intimated that, because of the strict hierarchical authority structure in many schools for Black learners, unless a task was assigned by the principal it would not be undertaken. Where their comments have relevance to, or help explain, the results of the national survey, the contributions of those who piloted the questionnaire are included.

As reported in Chapter Three, of the 1 410 questionnaires that were despatched only 178 were returned and were available for use in constructing a profile of educators teaching Geography at schools across South Africa. In section A of the questionnaire, access to learning materials, teaching aids and educator training were evaluated. Most of the questions in this section were of a general nature and could be answered by all 178 educators who responded (whether their *MapTrix Kits* had been received or not). Many participants left spaces blank and therefore only ticked answers and written responses were analysed. No answers were assumed to be either positive or negative by default.

6.2.2 Results

- Geography teacher profile

Geography teaching experience of 178 respondents ranged from 1 year (or less) to 30 years with a mean of 9.8 years, closely matching the pilot survey group whose mean years of experience was 9.5. Of the available population sample, 112 educators (62.9 %) felt that they had originally been adequately prepared to teach map use but only 100 (56.2 %) indicated that they still felt confident of their map use skills. Of the pilot group, only one felt that he had been adequately prepared during initial teacher training but four of the six had made the effort to upgrade their own skills and currently felt confident to teach map skills.

From the national survey six (3.4 %) believed that using *MapTrix* could not improve their skills further and 11 (6.2 %) were undecided. The majority of the educators who responded, 161 (90.4 %), believed that using *MapTrix*, which is intended to teach basic map reading only, could lead to an improvement in their own map use skills. All but one of the pilot group felt that *MapTrix* could probably improve their skills further. While this was the first indication of a positive attitude towards the learning programme, it also confirmed that teachers had low levels of confidence in their own map skills.

- Availability of resources for teaching map skills

With regard to resources available at their schools, 135 (75.8 %) educators felt that these were not adequate for the general needs of their schools and 139 (78.1 %) indicated that their geography resources were particularly inadequate. Three of the pilot teachers felt that resources were adequate for general teaching but only two of these felt that their geography resources were adequate. The other three educators thought that neither the general needs of their schools nor those for geography teaching were being met. In discussion with the pilot survey participants, it was agreed that it would be useful to provide an opportunity for teachers to list explicitly those items which they needed. This was added to the final questionnaire format.

Of the group that indicated inadequate resources, 84 % (117 of 139) took the trouble to comment on the resources not available to them for teaching map use to their geography classes (Table 6.1). As with the analysis of all comments solicited in the survey, words or phrases were noted as they appeared, repeat incidents were recorded and similarities grouped into categories.

The plight of 23 of the 117 educators who commented (19.6 %) appeared quite desperate. Of these, 15 required 'everything' or 'anything to help us' and eight indicated the need for an equipped geography classroom. In most cases, educators were less vague and 94 of them listed the specific items they required. In Table 6.1 the requested items are ranked according to most urgent need.

Table 6.1 Resources required for teaching map use, mentioned specifically by 94 teachers who responded to the *MapTrix* Questionnaire, that were not available to them at their schools

Category of equipment	Type of equipment required by teacher	Number of times listed	Total per category	Percentage of teachers requiring resources
Maps	General	38	119	100 % + (Some teachers listed various kinds of maps individually)
	Topographic maps	40		
	Local topographic map sheets	23		
	Aerial photographs and/or orthophoto maps	18		
Special equipment	Globes	18	51	54 %
	Compasses	6		
	Stereoscopes	12		
	Measuring wheels	4		
	Mathematical equipment	6		
	3D models	5		
Electronic equipment and accessories	Overhead projector	5	34	36 %
	Transparencies	1		
	Television and video machine	14		
	Videos	10		
	Computers	2		
	Slide Projector	1		
	Light table	1		
Texts	Text books	11	20	21 %
	Atlases	5		
	Sundries (exercises, syllabus etc)	4		
Training and/or assistance	Workshops on map use	6	8	8 %
	Senior/ additional educator	2		

Resources required for teaching map use at the under-resourced schools in the pilot survey included: local maps such as topographic maps and orthophoto maps in sufficient numbers to allow at least shared use by pupils, a dedicated geography classroom to leave teaching materials on display, instruments such as rulers and protractors, stereoscopes and a 3D landscape model. The general teaching requirements list included: overhead projectors, video machines and monitors (television sets), geography text books and smaller class numbers. Resources available at these schools were limited to insufficient numbers of maps from past examination papers. One educator indicated that he had a map use textbook and a black-board protractor with which to demonstrate the measurement of bearing but that his learners could not afford to buy protractors with which to practice this task. One educator was unaware that specific textbooks on map use were available.

Table 6.2 Resources for teaching map use that were available to 152 geography teachers who responded to the relevant section of the *MapTrix* Questionnaire

Category of equipment	Type of available equipment listed by teacher	Number of times listed	Total per category	Percentage of teachers that had resources (per category)
Electronic equipment and accessories	Overhead projector Videos	1 2	3	2 %
Special equipment	globes stereoscopes mathematical equipment	9 3 2	14	9.2 %
Texts	Text books atlases sundries (exercises, syllabus etc)	14 5 2	21	13.8 %
Maps	Unspecified map stocks • some • enough Topographic maps, aerial photographs and/or orthophoto maps (from past exams)	 32 28 17	77	50.7 %

There was also a question dealing with the resources that were available in geography classrooms. Of the 178 educators who responded 26 (16.3 %) indicated that they had adequate resources and no needs. They did not itemise what was available to them. The resources available to the other 152 who listed items are summarised in Table 6.2. The availability of maps was mentioned 77 times but in only 28 cases were the supplies adequate for the sizes of their classes. In the pilot study, only two of the six educators indicated that their schools were adequately resourced. They listed the resources available to them for teaching map use provided by their schools as: sufficient maps both in variety and quantity (both purchased and from past examination papers), a map use text book for each learner and stereoscopes. They also indicated that their learners purchased equipment such as rulers and protractors.

- *MapTrix* as a teaching resource

Designed as an introductory programme for map reading, *MapTrix* was not designed to meet all the needs of learners preparing for the matriculation practical paper for Geography, yet 43 educators (46.7 %) felt that it did so. This was also reflected by the fact that educators recommended Grade 12 almost as often as Grades 10 and 11 as the most suitable Grade for using *MapTrix*. However, 87 (94.6 %) concurred that a self-instruction programme for map analysis would be helpful. While two teachers in the pilot survey also felt that *MapTrix* met all the needs of learners preparing for the practical paper, they too concurred that a self-instruction programme for map analysis would be helpful. This disparity between needing help to teach the full range of map use skills (map reading, analysis and interpretation) and needing help to teach only map reading suggests that the teachers' main priority at poorly resourced schools is simply achieving a pass for candidates in the practical examination. They do not appear to aspire to assuring that their learners can master the full range of map use skills.

- Use of local maps

It is recommended in the *MapTrix* Educator's Guide that the local topographic map should be on display in the classroom while the Kit is being used and that learners should be encouraged to locate familiar features to help them build up their cognitive maps to match as closely as possible the cartographic map of their environment (Lynch, 1973; Stea and Blaut, 1973b). When asked whether they had done so, only two educators (of 96) had in fact complied. Both agreed that their learners showed an interest in the local map and that they were able to identify familiar local features but only one felt that this had improved their attitude to map reading. None of the teachers had used a topographic map for local fieldwork or for environmental studies.

- Availability of computers for teaching Geography

A question was included to gauge whether conversion of the *MapTrix* programme to a computer-based training programme would render it more useful in schools. Five of the six pilot schools had computer terminals available to learners but they could mostly be used only by a few individuals at a time and not by large class groups. Of the 96 teachers who evaluated *MapTrix*, 44 (47.8 %) reported that their schools possessed computer terminals available to learners but limitations on their computer use was unfortunately not assessed. Limitations on geography learners' access to school computers was later identified in the intervention with teachers that is discussed in section 6.4.

6.2.3 Discussion

The response to a national survey to evaluate the *MapTrix* learning and teaching support materials (LTSM) for topographic map reading was poor and thus may not be fully representative of all schools where Geography was being offered to Grade 12 at the time. However, certain trends were clear from those who did respond indicating that the majority of schools were under-supplied both in material and adequately trained human resources. Of the teachers who responded, 78 % lacked adequate resources for teaching map use and only 56 % of the 178 senior geography teachers surveyed were confident of their own map use skills, 90 % believing that their skills could be improved by a basic topographic map reading programme. Perhaps the most important finding in relation to the current investigation is that 95 % of geography teachers agreed that a self-instruction programme for map analysis would be a valuable resource.

6.3. COLLABORATION WITH EDUCATORS IN LTSM DEVELOPMENT

6.3.1 Background

When evaluating *MapTrix*, educators confirmed that more advanced exercises were required to develop learners' ability to analyse and interpret spatial information. The final section of the *MapTrix* Questionnaire (Appendix 3.1 page 4) carried an invitation to educators to collaborate in the development of learning materials for map and photo analysis (and interpretation). All except the least experienced educator in the pilot study enthusiastically agreed to be part of this process. In the national survey, while 61 educators (66 %) indicated that they would like to participate in the development of an advanced version of *MapTrix* (by ticking a yes box), as it transpired only three of the 92 correctly followed the instructions for selecting work cards in order to participate in this process. A total of 20 educators partially followed instructions, nine naming preferred topics, five preferred places (whether included in the *MapTrix* programme or not) and others indicating only one work card or a suit of cards (and not three work card choices as requested). This finding was most disappointing as the proposed collaborative writing process would have relied heavily on written instructions to co-authors. Following this failed attempt at collaboration with teachers in the development of LTSM for map analysis it was some time before a second opportunity arose.

6.3.2 Materials and methods

- Population sample

Lotz (1996) identified the advantages of seeking collaboration with practising teachers in the LTSM development process. One was the greater likelihood of adoption of the materials through ownership of the process. Another was that they would identify more realistically achievable learning outcomes. A valuable opportunity to involve educators in collaboration presented itself during eight workshops on *Developing spatial competence at global, continental, national and local scales* offered by the Western Cape Education Department (WCED) in collaboration with the NMO during February 2003. Included in the range of spatial information resources provided to the schools at these workshops were *MapTrix Kits*, a world-map learning game, a globe, wall maps of the World, Africa, South Africa and Western Cape as well as ten each of each school's local 1:50 000 topographic and 1:10 000 orthophoto map sheets.

Three representatives from each of 124 secondary schools were invited to participate in the training workshops where the resources were handed over. Of the 372 geography teachers invited, 192 arrived to attend the workshops. Although the numbers were disappointingly low, at least those who had arrived were willing to put in the extra effort required to improve their skills and knowledge with regard to developing the spatial competence of their learners. During three hours of the four hour workshop programme various aspects of teaching spatial competence were covered with the teachers from Grades 10, 11 and 12. For the remaining hour participants were divided into two groups. The Grade 10 and 11 teachers played *Mapa*, used the Smith GlobeMaps® and assessed them and the accompanying Mini Atlas (Anderson and Innes, 2003) as low cost resources for developing spatial skills. The 108 Grade 12 educators, responsible for preparing learners for the geography matriculation examination, participated in the collaborative writing of map analysis exercises. In hindsight, this investigation had the characteristics of a case study, incorporating as it did an active research element and identifying phenomena about which generalisations were possible due to the scope of the investigation (Yin, 1994).

- Map selection for spatial analysis learning programme

In Chapter Five the process of identifying the eight most important map analysis skills and their appropriate ranking into a learning hierarchy was discussed (see Table 5.6). For the original *MapTrix* programme, as explained in Chapter Three, topographic map extracts had been selected to illustrate the geographic themes of rural settlement, urban settlement, landscape and transport which were identified by suites of playing cards and using odd numbered, even numbered and picture cards (see Table 3.2) to differentiate sub-topics within each theme. Of the 52 map extracts used for *MapTrix*, the 16 odd-numbered and 20 even-numbered work cards were regrouped to teach eight spatial analysis skills[1] (as listed in Table 6.3).

- Instructions for writing questions and answers for the map analysis exercises

The guidelines for producing outcomes-based learning opportunities, provided in the draft Curriculum 2005 documents (DoE, 2002b), were consulted and adapted following the guidelines of Gagné and Briggs (1974) and Alexander and Blanchard (1985) to provide instructions for the educators for each of the eight spatial analysis tasks (Appendix 6.1, pages i – viii). Instruction

[1] The rest of the maps, which are identified by the 16 picture cards in the playing card deck, have been reserved for developing learning materials for spatial interpretation at a later stage.

sheets were affixed to the relevant work cards in each group (e.g. Boundary instructions were stapled to *MapTrix* work cards Hearts 3, 5, 7 and 9).

Each instruction sheet contained the following information:

- Name of the map analysis lesson
- Reference to the group of MapTrix work cards (e.g. Hearts ♥ Odd numbers)
- The assumed prior knowledge required for the map analysis task
- Where the specified task fitted into the difficulty ranking amongst the other 7 tasks
- A selection of key questions to guide the formulation of specific map related questions
- A list of learning outcomes to be achieved by the learners to demonstrate competence
- Suggested appropriate teaching resources with an invitation to add more

The instructions for question formulation provided the following guidelines:

- The kind of geographic or cartographic content (including appropriate terms and descriptive words) that should be used relative to the topic
- Format guidelines for short, unambiguous answers as required for self-assessment
- Suggestions for how to proceed with the task

Educators were each asked to formulate ten questions with matching answers that would provide learners with the opportunity to perform one of the required analytical tasks. The need for providing clearly worded questions that focussed on one possible answer only was identified as being in line with outcomes based teaching strategies. Lack of ambiguity is imperative for self-instruction learning programmes where learners assess their own answers against the model answer provided. The mathematical nature of such questions was stressed. The selected skills hierarchy was carefully described and explained before *MapTrix* work cards with attached instruction sheets were distributed randomly to the educators. They were offered the option to exchange one map analysis task for another if they so chose. Having taken approximately half an hour to introduce the learning materials, the educators then had half an hour to complete the exercise.

6.3.3 Results

If each of the 108 educators had compiled ten questions and answers (totalling 1 080), the result of the collaboration exercise would have produced 30 questions for each of 36 work cards from which the ten best or most appropriate ones could be selected for the prototype learning programme. The results laid out in Table 6.3 tell a different story. The 108 educators collectively submitted only 694 questions. After careful scrutiny 486 (or 70 %) were rejected. Only 137 or 20 % could be used as provided. Rejected questions were later re-evaluated and, in cases where they referred to the topic, practical map analysis or were relevant to the life experiences of adolescent map users, they were adapted for use in the programme. This led to a further 71 questions (10%) that could be included either by adding information to the questions or reformulating the answers.

Table 6.3 Comparison between questions formulated by educators per spatial analysis task and those that could be used in the map analysis programme

Spatial analysis task	Work card	Number of educators	Questions				
			Supplied	Rejected	Adapted	Accepted	Total
Identifying boundaries and shapes	H3	4	32	24	6	2	8
	H5	2	8	6	2	0	2
	H7	2	12	8	2	2	4
	H9	1	4	2	1	1	2
Describing direction	C3	2	16	12	1	3	4
	C5	5	30	21	1	8	9
	C7	3	27	17	1	9	10
	C9	3	20	14	3	3	6
Identifying absolute location (co-ordinate position)	H2	4	29	20	3	6	9
	H4	2	11	6	3	2	5
	H6	3	19	18	0	1	1
	H8	3	20	11	0	9	9
	H10	4	23	20	0	3	3
Measuring bearing	C2	3	15	11	1	3	4
	C4	4	16	6	4	6	10
	C6	3	15	10	2	3	5
	C8	4	27	17	3	7	10
	C10	3	15	12	2	1	3
Estimating height	D3	4	25	22	3	0	3
	D5	4	25	17	5	3	8
	D7	2	17	11	2	4	6
	D9	3	18	17	1	0	1
Calculating distance and area	D2	3	18	12	2	4	6
	D4	3	19	9	3	7	10
	D6	4	23	20	0	3	3
	D8	3	17	8	4	5	9
	D10	2	8	3	2	3	5
Calculating gradient	S2	4	31	21	5	5	10
	S4	3	23	13	2	8	10
	S6	2	13	10	1	2	3
	S8	3	22	19	2	1	3
	S10	3	20	17	0	3	3
Constructing profiles	S3	2	16	15	0	1	1
	S5	3	25	15	1	9	10
	S7	3	23	14	0	9	9
	S9	2	12	8	3	1	4
Totals	**36**	**108**	**694**	**486**	**71**	**137**	**208**

H = Hearts, C = Clubs, D = Diamonds, S = Spades

A total of 208 questions could be used in the self-instruction programme for spatial analysis from the collaboration exercise. This represented 58 % of the 360 questions required. The rest of the questions were totally unsuitable for inclusion in the LTSM. Of the 36 spatial analysis exercises requiring ten questions each, only seven (less than 20 %) were ready for the prototype learning programme at the end of the collaboration activity.

6.3.4 Discussion regarding educator training needs

It appeared that not all the educators involved in this exercise were aware of the distinction between reading, analysing and interpreting the spatial information on maps. Many found the task of setting questions very difficult with only 15 submitting ten questions while nine submitted only two or three, the average being 6.4 questions submitted per educator. With the stress on the outcome of teaching (rather than on the content as was formerly the case) the formulation of appropriate exercises is vital if geography educators are to be able to assess whether learners can attain the map use competencies expected. If the incidence of question rejection can be linked to lack of educator competence, then the ranking of the spatial analysis tasks in Table 6.4 may suggest the areas where educator training is most necessary.

Table 6.4 Ranking of spatial analysis tasks according to lack of educator ability to write appropriate exercise items

Spatial analysis skills requiring mathematical competence	Questions rejected per spatial analysis task
Estimating height	78.8 %
Calculating gradient	74.5 %
Identifying absolute location (co-ordinate position)	72.0 %
Constructing profiles	70.3 %
Describing direction	69.5 %
Identifying boundaries and shapes	66.7 %
Measuring bearing	64.1 %
Calculating distance and area	57.1 %

An analysis of the reasons for rejecting questions was undertaken in order to identify the shortcomings in educator preparedness for the task that had been undertaken. From Figure 6.1, it is clear that the main reason for rejecting questions (22 %) was that they were so vague as to make the required analysis impossible or a correct answer unattainable. 17 % of the contributions had to be rejected because the answers were wrong and a further 12 % of questions referred to map information incorrectly. The questions rejected as too easy (15 %) were all map reading rather than analysis questions, while 12 % were rejected because the questions were irrelevant to the topic. In 6 % of cases the answers were too long to be used for a self-instruction programme where accurate self-assessment relies on short unambiguous answers. Only a small percentage of questions were rejected because they were higher up the analytical skills hierarchy (3 %) or beyond the scope of map analysis (4 %). Only (2 %) were rejected due to repetition.

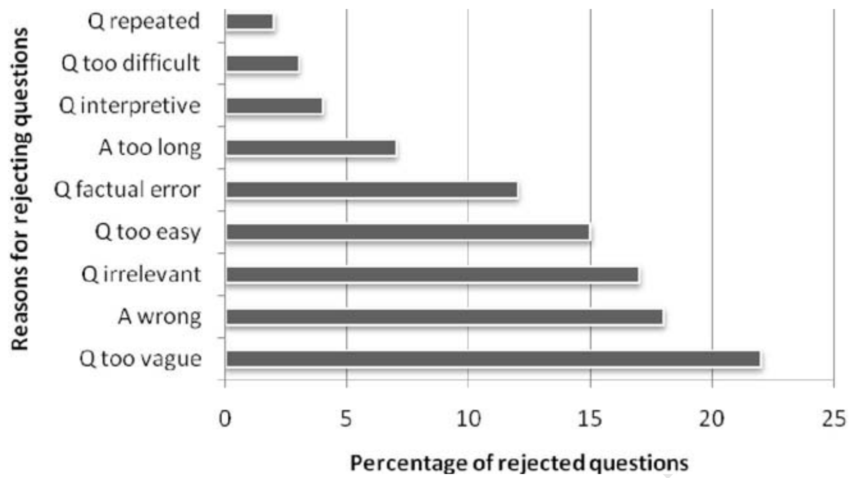


Figure 6.1 Questions that were rejected during the collaborative writing of exercises for the map analysis self-instruction programme (Q = question and A = answer)

No biographical details were solicited from the 108 educators who participated in this study in order to preserve their anonymity. The only factor that identifies the group is that they were all responsible for teaching Geography to Grade 12 learners in the FET band at their respective schools. As such, this group may not be representative of all senior secondary geography educators in South Africa. They were from schools in three of the eight management districts where the geography matriculation results for the previous year (2002) had been the lowest in the Western Cape Province; hence the reason for the department-sponsored intervention. However, in comparison with the other eight provinces in South Africa the WCED generally has better examination scores, confirmed by the examination results analysed in Chapter One and illustrated in Figure 1.4(a). It is also regarded as one of the provincial education departments leading the way in educational reform in South Africa (van Wyk, 2006).

It must be stressed that the gathering of questions for map analysis exercises was not undertaken in order to assess educator competence in this task but as a genuine attempt at collaboration in LTSM development. While the first attempt at long-distance collaboration, initiated during the *MapTrix* survey, had been unsuccessful, in this second attempt considerable success had been attained in light of the very short time available to the researcher for collaborative writing.

6.4 AVAILABILITY OF COMPUTER FACILITIES FOR GEOGRAPHY TEACHING

As part of a marketing campaign for their Grade 11 publications, Nasou Via Afrika (www.nasou.com) offered workshops to teachers at venues in various provinces during 2006. As a contributor to *OBE for FET Senior Geography* (Beets *et al.*, 2006a), the author had the opportunity to run seven map use workshops in the Eastern Cape Province and three each in Limpopo and Gauteng. During each of these workshops a show of hands was requested in response to the question "Do you have computers at your school?" Only one teacher per school was asked to respond. Table 6.5 lists the results.

Table 6.5 Availability of computers at schools as represented by teachers attending Grade 11 map use workshops in Limpopo, Gauteng and the Eastern Cape (2006)

Province	**District name**	**Description of area served**	**Number of teachers**	**Computers at school? Yes**	**Schools with computers %**
Limpopo	Kangwane	Urban, low income residential	5	5	100.00%
	Jane Furse	Nucleated rural	38	10	26.32%
	Tshedza	Nucleated rural	7	3	42.86%
Sub-totals			**50**	**18**	**36.00%**
Gauteng	Sebokeng	Urban, low income residential	6	5	83.33%
	Johannesburg	Major urban centre	10	6	60.00%
	Mamelodi	Urban, low income residential	6	4	66.67%
Sub-totals			**22**	**15**	**68.18%**
Eastern Cape	Butterworth	Small urban centre	6	2	33.33%
	Masibulele	Dispersed rural settlements	11	6	54.55%
	Bizana	Dispersed rural settlements	6	1	16.67%
	Flagstaff	Small urban centre	5	3	60.00%
	Umtata	Large urban centre	8	4	50.00%
	Fort Beaufort	Small urban centre	13	7	53.85%
	Port Elizabeth	Major urban centre	13	8	61.54%
Sub-totals			**62**	**31**	**50.00%**
Total			**118**	**53**	**44.92%**

When asked whether they had access to these computers for teaching Geography, not one teacher responded. Further informal discussion revealed that in most cases there were only a few computers and they were used for school administration and not for teaching. Of all those that indicted that there were computers at their schools, only four revealed that they had computer laboratories but they could not use them to teach Geography because other subjects (IT, Mathematics or Languages) had precedence.

It must be stressed that this was an opportune sample of geography teachers attending voluntary training and may not be representative of all teachers (or all schools) but it is interesting to note that the most urbanised province, Gauteng, had more computer-equipped schools than the two less urbanised provinces. Overall, more than half the schools (55.08%) had no computers at all with the distribution skewed in favour of urban areas. If the percentage of schools with computers is classified according to rural areas, small urban centres and major urban centres, the breakdown is 35.10 %, 49.06 % and 70.26 % respectively. This approximately matches Matengu's (2006) findings when studying ICT distribution at schools in core and periphery areas of Namibia and the patterns of access to ICT in South African schools described by Lundall and Howell (2000). Although the importance of technology in education has been recognised and many schools are developing and implementing ICT school policies (Howie *et al.*, 2005) lack of resources does not bode well for wide adoption of the ICT use required for Geography. This is especially problematic in those peripheral areas where ICT adoption has the greatest potential to improve praxis.

6.5 CONCLUSION

The user needs survey embedded in the *MapTrix* Questionnaire clearly indicates that teachers do not all have the resources necessary to teach the map use component of the geography curriculum (Table 6.1). As discussed in 6.2.2, 43.8 % lacked confidence in their abilities to teach map skills. The survey was conducted before the proposed inclusion of GIS in the new curriculum became a reality. Basic map skills are a requirement for successful introduction of GIS (Coggins, 1990; Green, 2001b). It is clear that even before lack of IT facilities was added to the map skills problem, teaching resources and teacher training needed attention. A question regarding computers at schools revealed that 48 % had computers available but only 2 % indicated that they had access to electronic equipment and accessories (Table 6.2) to teach Geography. The results of the informal computers at school survey, conducted with teachers in three provinces during 2006, inspired little confidence for the adoption of IT to enhance learning in Geography in rural areas.

The limited success of the attempted collaboration in LTSM development (Table 6.4 and Figure 6.1) suggests a link between lack of teacher training and poor performance in the geography matriculation map use examination in South Africa as documented in Chapter One (Figures 1.3 and 1.4). Without improving their skills with some form of spatial competence training, teachers' abilities are not adequate to meet the needs of the learners who, in turn, are unlikely to meet the expectations of prospective employers in the rapidly expanding spatial information industry.

CHAPTER 7
INTERVENTION INSTRUMENTS, EVALUATION METHOD AND SETTING UP THE TRIALS

'Accurate perception is of considerable importance in effective conceptual learning'.
(Naish, 1982: 54)

7.1 INTRODUCTION

7.1.1 Background

Under Boardman's umbrella term *graphicacy* (1983), map skills include reading, analysing and interpreting maps (illustrated in Table 5.1). If map reading is about symbols, words and associated geographic concepts, then map analysis is about shapes, numbers and associated mathematical operations. Map interpretation is about bringing the symbols, words, shapes and numbers together to gain a better understanding of place, as it was, is and might become. GIS technology makes it possible '...to create flexible, computer-based learning materials that are rooted in authentic, real-world contexts, which aim to enhance (the) cognitive skills' (Stott, 2004: ii) providing an innovative method of teaching the spatial competencies expected of geography learners at the end of their schooling.

In Chapter Three the success of the paper-based, self-instruction *MapTrix* programme for teaching topographic map reading was demonstrated. In Chapter Four the need to incorporate mathematics instruction for map analysis was emphasised. In Chapter Five the help of a focus group in the identification and ranking of eight basic map analysis skills was discussed. In Chapter Six the collaborative development of the exercises designed to demonstrate competence in the map analysis tasks was described. The broad framework of a self-instruction programme for map analysis has been outlined. By writing exercises in collaboration with practising teachers, some of the learning outcomes of such a programme have been established. In this chapter, the preparation of the remaining features of the spatial analysis learning programme and their assembly are discussed.

When a plan for evaluating the map analysis programme was formulated, it became clear that a strategy was required to ensure that trial participants were both computer literate and sufficiently capable of map reading to effectively trial the map analysis programme. This presented an opportunity to conduct a ‘trial within a trial’ because a prototype of the conversion of *MapTrix* into a computer-assisted learning game had fortuitously become available.

7.1.2 Reasons for using GIS to teach topographic map analysis at school level

When research was initiated into developing learning materials for map analysis, it was proposed that a companion paper-based learning programme would result, which would be used after learners had gained competence at map reading with *MapTrix*. The activities reported in Chapters Three to Six had already been completed when the author was introduced to the use of GIS for educational purposes. At the May 2005 ‘GIS Week’ hosted by the Geo-information Society of South Africa (GISSA) exhibitors included two organisations that were developing GIS based learning materials for South African learners. One of the companies, Naperian GIS Technologies, was contracted to Fort Hare University in the Eastern Cape to run their GIS Honours programme. Lecturers had successfully used *MapTrix* to introduce map reading concepts to the students (pers. comm. Clyde Mallinson of Naperian GIS Technologies). The author described the progress of the research into developing the self-instruction advanced map skills programme based on *MapTrix*. A joint-venture was proposed incorporating the author’s learning programme design concepts (and lesson, exercise and answer text) and some elements of the computer-assisted learning programme for teaching basic GIS concepts and to combine them on a GIS platform which would deliver both the spatial data and the learning material.

The availability of digital versions of all topographic map sheets selected for *MapTrix* at no direct cost from the NMO (DLA, 2000), the inclusion of GIS in the geography curriculum (DoE, 2003), the policy of implementing technology in education (Lundall and Howell, 2000) and the offer of assistance from the creators of Geomatica™ together provided ample reasons to use GIS to teach map analysis. It was decided to name the envisaged programme – **MapTrix Geomatica** – and to develop a prototype for trialling.

Box 7.1
Evolving definitions of GIS

'A GIS is an integrated system of hardware software and procedures designed to support the collection, management, manipulation, analysis, modelling, and display of spatially referenced data about Earth's surface in order to solve complex planning and management problems. The power of a GIS is that it allows us to ask questions of data and to perform spatial operations on spatial databases.'

(Geography Education Standards Project, 1994: 256)

Initially, Geographic Information Systems had strong ties to geography, computer science, cartography, geodesy, remote sensing, and other disciplines; now, Geographic Information Science is more than just the sum of those parts – it has become its own distinct discipline, increasingly integrating internet-based data with software residing on a desktop computer. It is more than hardware, software, procedures, and spatial data; it is also a network of people who collaborate to solve integration and technical problems.

(after Kerski, 2008)

The first definition of GIS in Box 7.1 confirms why these systems are so valuable in the teaching of geographic and related spatial concepts. Of even more value is the fact that such systems mirror the way efficient spatial thinkers operate and might, in turn, assist in developing a capacity for spatial thinking in novice users of spatial information. It is suggested that this is because a GIS helps to answer questions such as: what is there, where is it, what has changed, what pattern is created, what if? and a dozen similar queries. Once a line of spatial questioning is stimulated by appealing to the natural curiosity of the young, and answers can be found easily (using GIS technologies), further possibilities are more likely to be explored. The use of GIS in education can thus promote spatial literacy which constitutes '...proficiency in terms of spatial knowledge, spatial ways of thinking and acting, and spatial capabilities' (NRC, 2006:18). The second definition points to the difficulties of implementing GIS in under-resourced classrooms with under-trained teachers.

7.1.3 Hypothesis

On the strength of the abovementioned practical and academic reasons, and despite the technical and training limitations that have been highlighted (Page *et al.*, 2001; Kerski, 2003; Baker and Bednarz, 2003), the main research goal of this chapter remains: to test the hypothesis that a self-instruction programme for spatial analysis can be developed and that it can be delivered on a GIS platform. The hypothesis rests on the following assumptions:

(i) GIS offers learners the opportunity to visualise and interrogate various sources of spatial data in an interactive, novel and stimulating learning environment.

(ii) GIS is extremely complex both in the variety of the data sets it can handle and the tools available to analyse the data. By introducing learners to the potential of GIS in very small incremental steps through relatively familiar topographic maps (as required at school level) they can be prepared for more extensive subsequent use of GIS for map interpretation.

(iii) The manual execution of map analysis tasks such as calculating distance and area and drawing profiles is time consuming and often inaccurate. By using a limited selection of GIS tools, the outcome of such tasks can be demonstrated instantly and repeatedly and used to guide the manual execution of the tasks.

7.2 INSTRUCTION DESIGN MODELS

MapTrix was designed using the guidelines of Gagné and Briggs (1974) and Alexander and Blanchard (1985) who were studying the development of computer-based learning programmes. Decades of research and development in this area, much of it influenced by behavioural psychology, have built up a significant body of knowledge leading to the formulation of various theory-linked models that have generally been divided between two paradigms – early behaviourist inspired models and more recent constructivist inspired models (Tam, 2000).

The instructional design process as described by Moallem (2001: 2) is '...the entire process of analysis of learning needs and goals and the development of an instructional system that meets those needs. It includes development of instructional materials and activities ... (and the) ... trial and evaluation of all instruction and learner activities'. He stresses the importance of matching the arrangement of the resources and procedures of the instructional design product with learning theories relevant to the acquisition of a body of knowledge or to the skill that must be learned. This emphasises the behaviourist approach suggesting that, with the correct arrangement of stimuli, behaviours and reinforcers, learning is bound to happen, agreeing with Anderson (1997: 521) who defines an instructional design model as a '...step-by-step process designed to achieve a particular educational outcome'.

To offer effective learning experiences Naish (1982) urges that the educator must take into account the previous learning, level of motivation and mental ability of learners in order to challenge them, stretching their understanding to new levels. It is important therefore to establish the level where learners are and where they can reasonably be expected to be in order to design relevant learning experiences for them to reach the expected level of attainment. Because there is a specific outcome of the proposed self-instruction programme - improved map analysis skills - the objectives model of planning, as described by Roberts (2002b), was selected. Clarifying the objectives of learning provides guidelines for deciding which teaching and learning activities should be used.

There has been much emphasis on the value of GIS in education although few definitive studies have emerged to show that it produces better results that other teaching strategies (Bednarz, 2000). This may well be because few other strategies have been developed which produce measurable improvements in spatial competence. Because the outcome of the process of teaching thinking skills is not easily measurable, instructional design products that are developed in this field of expertise fit better within the constructivist paradigm which is more focussed on formative rather than summative evaluation and considers subjective data more valuable than objective data (Tam, 2000).

Formative evaluation also has a role in behaviourist models, when it is used as a learning tool. While assessment itself does not help teachers teach better or learners learn better, it can be used to inform both parties of the progress being made towards improvement (Lambert, 2002; Sutton, 1995; Sadler, 1989). Not only can formative assessment be used to give learners feedback on the standards they have achieved, it can supply *feed forward* on what they need to do next to attain the required level of performance. By providing a structure within which self-assessment is encouraged and used effectively, learners can monitor their own progress and take action to improve performance but, for training in self-assessment to be effective, it should aim to '... break the pattern of passive learning, make learning goals explicit and establish the 'desired goal – present position – way to close the gap' mentality in pupils' (Lambert, 2002: 130). 'As a task becomes increasingly familiar, many aspects of the task may become automatic, requiring little conscious effort to determine what step to take next and how to implement the next step. A novel task makes demands on intelligence different from those of a task for which automatic procedures have been developed' (Sternberg, 2005: 763). When developing a skill such as map analysis, opportunities for practice are necessary for reducing the time and effort required for the tasks and thereby improving efficiency.

Stott (2004) has summarised constructivist learning theories for the purpose of developing a framework for evaluating instructional design models for computer-based learning using GIS technologies. In developing the higher order skill of interpreting spatial information, there is no doubt that a constructivist model of instructional design would be most appropriate with its characteristics of a non-linear design process which is organic, developmental and reflective; a process during which objectives emerge as work progresses and where the instruction emphasises the goal of personal understanding rather than knowledge acquisition or skill development. When the next phase of the research is undertaken (the interpretation of spatial information using the 16/52 picture cards in the *MapTrix* programme) then the guidelines of the constructivists will be most useful. However, GIS has been used in MapTrix Geomatica as a means to deliver learning material and not as a tool to foster spatial problem solving. In designing the map analysis self-instruction programme where the goal is to develop specific skills, the behaviourist model of instructional design is more appropriate.

7.3 STRUCTURE OF THE MAPTRIX GEOMATICA PROGRAMME

7.3.1 Exercise development

The starting point in designing computer-based training, according to both Gagné and Briggs (1974) and Alexander and Blanchard (1985) is task analysis: define the outcomes of the learning programme and work backwards from these to identify the knowledge and skills that are required to produce these outcomes (Figure 5.1 and Table 5.2). The first component of the programme to be completed within the framework of eight map analysis skills was a set of exercises based on 36 of the 52 map extracts from *MapTrix* (see the first two columns of Table 6.3).

The questions and answers contributed by teachers (as per the last column of Table 6.3) formed the basis of each exercise and further questions and answers were written, totalling ten per exercise. It was possible to differentiate the exercises so that some were less complex than others. These differences in difficulty level were then used to structure the programme so that some exercises required only basic lesson material while others required more advanced concepts or techniques. Table 7.1 illustrates how learning materials were differentiated for two levels of complexity, designated as A and B lessons, reflecting the progression expected in the curriculum from Grade 10 to more complex concepts in Grade 11 (see Table 2.3). The prototype was developed to teach the foundation concepts in the A lessons only.

Table 7.1 Proposed structure of self-instruction programme for map analysis skills lessons with GIS and Mathematics sub-lessons (based on 36/52 topographic map extracts selected for *MapTrix* work cards)

Lesson number and title Related exercises	**Map analysis skills lesson content outline**	**GIS sub-lesson content outline GIS Practice**	**Mathematics sub-lesson content outline**
How to use the lessons in this programme		**Introduction to GIS** Hyper-index navigating, legend view, zoom icons	
1A Boundaries Hearts 3 and/or 5	Boundaries on small scale maps Your local boundary Boundaries on topographic maps	**B. Position in a GIS** Open data layers Zoom to named positions Identify position information using legend view	
1B Boundaries Hearts 7 and/or 9	Catchment management Rivers and watersheds as boundaries	Select layers (hydrology), identify features (drainage patterns and catchment areas)	
2A Direction (from one place to another) Clubs 3 and/or 5	The compass rose, naming and abbreviating direction Describing direction between places		
2B Direction (of slopes and movement) Clubs 7 and/or 9	Wind direction Direction of water flow Slope aspect	Digital Elevation Model (DEM) Raster images Slope maps	
3A Position (geographical location) Hearts 2 and/or 4	Latitude Longitude Coordinates SA Topographic map sheet reference system	**B. Position in a GIS** Position report Name places from given coordinates Give coordinates of named places	
3B The Global Positioning System (GPS) Hearts 6, 8 and/or 10	Size and shape of the Earth (geoid, ellipsoid, graticule) Components of the global positioning system (GPS)		
4A Bearing Clubs 2 and/or 4	North line Join place *from* and place *to* Measure bearing	**C. Bearing (Heading) in a GIS** Using GIS line tool to read heading	**USING THE CORRECT INSTRUMENTS** Setsquare, ruler, 360° protractor
4B Magnetic bearing Clubs 6, 8 and/or 10	History of magnetic bearing Magnetic declination Calculate magnetic bearing Bearing and intervisibility		

Table 7.1 cont:-

5A Height Diamonds 3 and/or 5	Reading vs. analysing height information Contour lines	**D. Height concepts in a GIS** DEM's Contours and spot heights (data tips)	
5B Slope aspect and drainage basins Diamonds 7 and/or 9	Shadows and slopes Shadows and vertical aerial photographs How to outline a drainage basin on a map	Sun-shaded DEM's Hill shading on maps	
6A Distance and area Diamonds 2, 4 and /or 6	Measuring distance using different map scale formats: line scale, word scale, ratio scale, representative fraction	**E. Scale in a GIS** Changing units of measurements Zoom in = large scale Zoom out = small scale **F. Measuring distance** GIS line drawing (and measuring) tool **G Measuring area** Selecting and stretching regular shapes to measure approximate area	**AREAS AND SHAPES** Recognising regular shapes Calculating areas of regular shapes Appropriate units of measurement
6B Distance and area Diamonds 8 and/or 10	Measuring and calculating irregular line distances using: String Pivot and swivel	Chains, nodes and the links between them	Distance and time calculations Measure and calculate areas of irregular shapes by: combining regular shapes Using a grid of squares
7A Gradient Spades 2 and/or 4	What is gradient? Slope length vs. map distance Calculating height and distance Expressing gradient as a ratio		
7B Gradient and slope forms Spades 6, 8 and/or 10	Recognising slope elements Identifying slope forms		
8A Profiles Spades 3 and/or 5	What is a profile? Recognising an area on a map from a profile Using map data to draw a profile	**H. Profiles in a GIS** Use line tool to identify a line to profile Use the profile tool to draw the profile	
8B Long profiles and vertical exaggeration Spades 7 and/or 9	What is a long profile? How to draw a long profile What is vertical exaggeration? Calculate the vertical exaggeration of a profile	Profiling an irregular line to create a profile	Express vertical exaggeration as a ratio

Shaded sections used in the computer assisted prototype learning programme provisionally named MapTrix Geomatica

7.3.2 Lesson design elements

The lesson design elements had been identified, and much of the lesson text had been written before the joint-venture development with Geomatica was proposed. Having identified the desired outcomes of the programme and formulated the exercises that would assess whether those outcomes could be met, informed the decisions regarding the knowledge and skills that had to be covered in the content of each lesson. The task analysis method (Table 5.2) had helped to organise the lessons into a hierarchy of progressive difficulty. The lesson design elements are illustrated in Box 7.2 and briefly described.

- Lesson title is a map analysis skill and also names the topic of the lesson

The MapTrix Geomatica programme consists of lessons (and exercises) on eight specific map analysis skills. The hierarchy used to develop the map analysis skills was based on task analysis and guidelines offered by industry representatives and members of the Commission on Children and Cartography in the International Cartographic Association (as discussed in Chapter Five).

- Why learn about it?

The importance of making learning relevant was stressed by Sandford (1986 and 1989) and others. Highlighting, at the start of each lesson, *who* might find the information important and *why* was included to motivate learners to take an interest in the topic. If possible, discourse should be encouraged between learners so that they can articulate their understanding, especially of terms that have special significance in Geography (Butt, 2002). With a map substituted for text, Owen (2003) also found that discourse between learners at a computer terminal enhanced learning.

- Terms that must be understood

The task analysis method was used to identify the prior knowledge required for each lesson. This was listed as the terminology that would have to be understood. Each of these terms was identified and classified as either a geographic, cartographic or mathematical term, carefully explained and placed in an alphabetical glossary. The terms relevant to each lesson were then identified and presented at the start. Butt (2002) placed much emphasis on using appropriate language for learning in Geography. This is important in the level of complexity in written texts as well as the terminology used by the teacher when giving oral or written guidance and instructions and especially when asking questions. A simple reading strategy that has been shown to improve student retention and understanding is one in which readers interact conversationally in small groups around a text with directions to question, clarify and summarize (Brown and Palincsar, 1982).

Box 7.2

Lesson design elements of the prototype MapTrix Geomatica Programme

Each lesson in the prototype of the MapTrix Geomatica Programme for learning to analyse spatial information contains some or all of the following elements (see Appendix 7.7, relevant slides from Lesson 1 are indicated in *italics* below):

- Lesson Title
    - Each title is task related e.g. Identify boundaries, Describe direction etc
- Why learn about (the title)? *(slide A)*
    - Practical real-world relevance e.g. Position and co-ordinates are the basis of all modern systems for mapping, managing and improving the environment using GIS
- Before you start, make sure you understand the following terms: *(slide B)*
    - Tabulated glossary which includes

Term	Definition (with reference to spatial information)	Words with similar meanings plus explanations and/or examples

- What you need to know NEXT about (the title) *(slides C to G)*
    - Main body of the lesson explained with variations in text colour and font, practical hints, animated illustrations and screen shots from maps etc
- RULE or key concept *(slide H)*
- Mathematics sub-lesson
    - Explanation with examples of the mathematical operations relevant to the title e.g. the formulae for calculating area of a square, triangle and circle
    - In many cases mathematical concepts were also dealt with in the main skill lesson and glossary
- GIS sub-lesson *(slide I)*
    - Where relevant and introducing only those concepts and tools required for the specific analysis task
- GIS practice *(slides J and K)*
    - Activate the link to a digital atlas of South Africa with various data layers and including selected topographic map sheets with matching vertical aerial photography, satellite images, DEM's, sun shaded DEM's etc and perform tasks related to the lesson title
- What do you need to be able to DO: *(slides L and M)*
    i. to show real world understanding - answer a series of questions relevant to the title, that are evident in the learner's environment
    ii. with maps - including a list of specifically named map analysis tasks with examples
- Demonstrate your ability to perform the lesson tasks manually, using a topographic map by: *(slide N)*
    i. writing down the answers to the questions on one of 2 exercises (identified by playing cards)
    ii. marking your answers.
    - If you get less that 8 out of 10 for the first exercise, complete the other exercise. Aim for 8 out of 10 to show that you have mastered this spatial analysis skill.
- What next? *(slide O)*
    - Move on to the next lesson on the skills ladder.

DEM = digital elevation model

- What you need to know next (new knowledge that has to be learned)

Lessons comprise various learning materials presented to the learner on screen as text (using different fonts and colours to emphasise different concepts), animated graphic illustrations and video clips using screen shots to demonstrate the use of icons. The material is designed to assist learners to understand a new concept or learn the techniques required for a new skill. Sometimes, background information is presented in a CHAT BOX. Where a technique is illustrated, the step by step method is clearly described with examples.

- RULE or key concept

A screen summary focuses attention on the main new piece of information

- Mathematics sub-lesson

Part of the learning material for some lessons in the MapTrix Geomatica programme includes sub-lessons to teach mathematical skills and concepts (see the last column in Table 7.1). In some cases these are included within the main skill lesson and not identified specifically as a mathematics lessons

- GIS sub-lesson

In Table 7.1 the GIS sub-lessons A to H are outlined. It must be acknowledged that the material for these lessons was supplied from Geomatica and linked to the text supplied by the author. Only those GIS lessons required to teach the A lessons (for Grade 10) in the prototype programme have been prepared. If the trials of the MapTrix Geomatica prototype prove successful, further GIS lessons will be prepared.

- GIS practice

Guided activities using the various data layers in the digital atlas and selected tools are undertaken by following on-screen instructions. These are offered to help learners get a sense of the types of information they should be deriving from manual execution of the tasks required in the exercises.

- What you need to be able to DO

Suggested activities for discussion and/or investigation relate to real world application of the map analysis skills. Learners are placed in the role of map users in their own local areas where possible and given tasks with local relevance. The digital atlas accompanying the programme contains the data for South African relief, hydrology, administration, climate, transport and more, providing a valuable resource to support learning across the geography curriculum and to provide background data to investigate local issues with or without accompanying local topographic maps and aerial photographs. This approach is strongly recommended by many researchers (Walker, 1976; Naish, 1982; IGU CGE, 1992; Wiegand, 2006a and b) and supports the requirements of the curriculum for conducting local studies, including fieldwork (DoE, 2003).

- Demonstrate your ability

Learners are instructed to complete one of the exercises related to the topic. Each exercise comprises ten questions which direct the learner to perform the tasks that provide evidence that they have acquired the relevant map analysis skill. Once they have finished answering the questions, they open the model answer sheet and assess their answers. Successful completion (a high percentage of correct answers) shows whether they have attained competence in the execution of the tasks based on the map analysis skills. If their success rate is less than masterful (80 %), they are instructed to attempt another exercise to gain more practice.

- What next?

Guides the learner to the next lesson in the skills hierarchy

7.3.3 Structure of the MapTrix Geomatica prototype

MapTrix Geomatica has a two-part computer-linked structure using two different software packages, *viz.* GIS, containing all spatial data in a digital atlas, and the operating files. The learning materials (lessons, exercises and answers) are presented on PowerPoint. The user moves constantly between programmes (preferably using the *alt* and *tab* keys).

- The GIS component

Naperian GIS Technologies are the creators of the Geomatica^{TM} product suite. This South Africa focussed, GIS based learning material is designed to expose teachers and learners to key subjects such as Mathematics, Science and Information Technology but also incorporates History, Social Sciences and other learning areas (www.geomatica.co.za). One of the principles upon which their product offering is based is forming relationships with product users. They provide initial training and website support and assistance to teachers, focussing on the provision of skills and resources for project-based activities across a range of subject areas. Their start-up GIS lesson was adapted and used to introduce the GIS component of the MapTrix Geomatica programme to all trial participants (Appendix 7.6). The organisation's emphasis is on supporting teachers to use technology in education in an interactive classroom environment. Updates are regularly incorporated in keeping with the best practices of constructivist models of instructional design (Stott, 2004).

A synergy clearly exists between using a GIS to encourage learning across the curriculum and using GIS to develop map use skills. While Geomatica encompasses a cross-curricular approach, the aim of the current research is limited to the development and evaluation of a self-instruction method for the analysis of spatial information. Although a comprehensive data set of South African maps is used to illustrate certain tasks and GIS functionality, the assessment of analytical competence is based on topographic maps only.

The original selection of map extracts for *MapTrix* was conducted between 1994 and 1996 (Table 3.1) at a time when map symbols had been adapted for digital map production but the whole country had not yet been remapped. When preparing the exercises for the current programme, the most up to date topographic map extracts of those originally selected for *MapTrix* were used. To ensure coverage of all nine provinces in South Africa some maps in the original selection were replaced by extracts covering a new selection of areas. Using the TNT range of GIS software programmes from MicroImages, a digital atlas was developed which incorporated a range of data focussing on each selected topographic map extract. This included the raster and vector data for the full topographic map sheet, an alphanumeric reference grid for the selected extract plus satellite images, colour or black and white aerial photography and orthophoto maps (where available).

To put each extract into context, the software presents the geo-referenced map extracts linked to the South Africa data set, which includes layers showing boundaries (down to municipal level), infrastructure, climate, relief and hydrology. The digital elevation model (DEM) can be either sun-shaded or layer tinted (or both) to enhance the relief presented by contour lines. When the sun-shaded DEM is visible behind the slightly transparent topographic map extract, it dramatically enhances visualisation of the relief of the area, greatly assisting learners to understand the representation of relief by contour lines.

A GIS toolkit is available so that measurements such as distance, bearing and area can be made. Profiles (cross-sections) can also be drawn instantly on screen and used to guide or check those produced manually. References to the spatial datasets incorporate the playing card suites and numbers used for the *MapTrix* original.

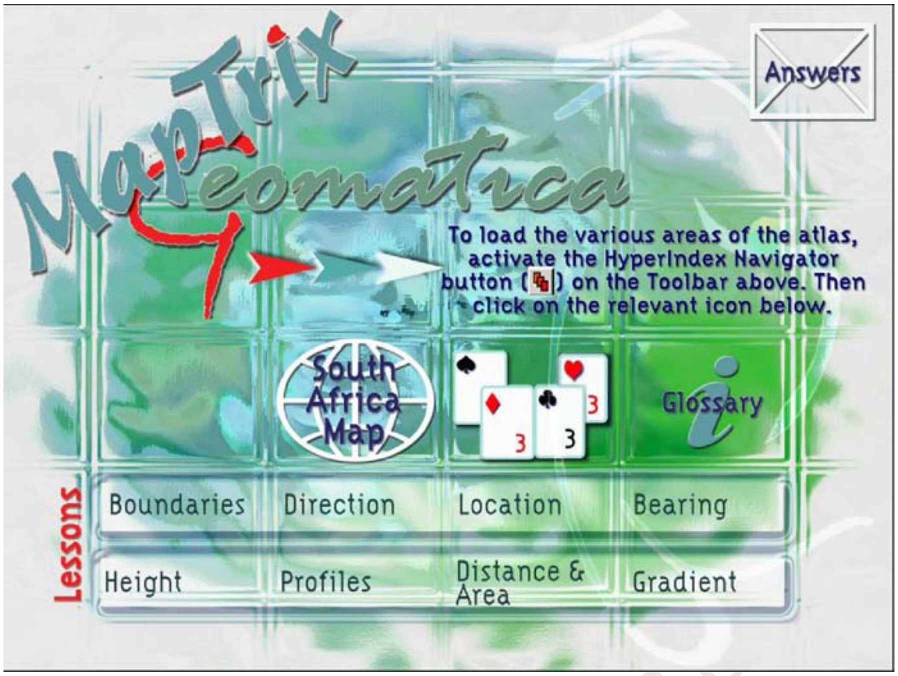


Figure 7.1 Prototype MapTrix Geomatica homepage showing some of the components of the programme: the 8 lessons on the lower bars, exercises indicated by playing cards, answers in the envelope, South African data accessed via the globe and the glossary. Links between the components are only possible when the hyper-index navigator icon (button) is active

- The PowerPoint component

A carefully structured self-instruction programme was designed, based on the guidelines reported earlier, to teach eight map analysis tasks. The design elements of each lesson are illustrated in Box 7.2. Sub-lessons on basic mathematical concepts and some elementary GIS functionality have been added to the relevant learning units (lessons). PowerPoint was used to present the learning material using concise and clear text, animated illustrations, voice-over explanations and short movie clips. The components are accessed via the hyperlinked GIS home page (Figure 7.1).

The lessons are identified on the active bars on the lower half of the homepage screen (Figure 7.1). The order in which the lessons appeared on the prototype homepage was unfortunately incorrect but trial participants were given the correct order to follow. Once learners click a lesson title, a lesson screen opens where they can either proceed with the skills lesson or select the Mathematics or GIS sub-lesson if relevant to the topic (Figure 7.2). Each lesson's opening screen also carries a reminder about how to use the lessons.

Figure 7.2 Sample lesson page: selecting the area inside the white boundary activates the main lesson, activating the GIS lesson button takes the learner to the GIS lesson and to the practice activities, the 'how to use the lesson' button is active on each lesson's front page

Learners follow each lesson, screen by screen reading and/or listening to information, considering the questions raised, activating animated illustrations or video clips (where relevant), interacting with the GIS software to locate features by using the various zoom tools or switching from one data layer to another (see examples of slides from Lesson 1 in Appendix 7.7). Step-by-step explanations of mathematical operations are supplied as well as examples of all calculations for relevant lessons. The glossary of terms relevant to each lesson is also available from the hyperlinked home page so explanations of unfamiliar terms can be accessed at any point in the programme, not just at the start of each lesson.

The questions in the exercises based on each lesson include reference to the skills learned in the previous lessons(s) so that these are constantly reinforced as the learner progresses through the programme. The exercises are in Adobe files. These can be accessed on screen or printed out and supplied to users to write their answers in the spaces provided on the question sheets (example in Appendix 8.5). To practice the manual map analysis skills as required for school based assessment, *MapTrix* work cards with the relevant map extracts are supplied so that learners can perform the measurement tasks manually. As they complete each exercise, learners can check and score their work using the model answers on screen.

7.4 PLANNING THE TRIALS OF MAPTRIX GEOMATICA

In attempting to improve map analysis performance, various teaching methodologies are available and may be compared to assess which one is best. The most effective method would doubtless involve expert map users with many years experience coaching each novice, although there are too many novices and too few proficient map users. The lecture method for teaching map skills is poor at invoking skills as it focuses on talk rather than practice. The computer-assisted methodology may be compared with conventional classroom methodology, although it is difficult to control the variables to ensure the same content in the same sequence with the same exercises. Comparing one method with another is therefore fraught with difficulty.

In order to measure whether improvement in learner performance may result from using a computer-assisted learning programme without some form of comparative study, the test-intervene-test method was adopted (Cohen and Manion, 1985). This empirical approach (Francis, 1997) to addressing the problem of poor spatial competence falls within the bounds of action research (Huysamen, 1994) which allows for the adaptation of the research agenda in light of changing circumstances.

Task analysis suggests that learners who cannot recognise, discriminate between and comprehend the map symbols used to represent the natural and constructed features of the landscape (i.e. cannot read maps), cannot analyse the statistical spatial information that the symbols represent. Before participants could embark on a map analysis programme it was important to establish whether or not they could read maps. If they could not read maps proficiently it would be necessary to improve their map reading skills before placing them on a map analysis intervention programme.

In the original research plan, participants would have been offered *MapTrix* as a pre-intervention strategy to improve their map reading skills. Some years before the development of the map analysis programme had been initiated, the conversion of *MapTrix* to the digital format had been proposed. In the next section the features and structure of the MapTrix Digital Game are described.

The flow chart in Figure 7.3 illustrates the test-intervention-test methodology planned for the trials. Information about participants was gathered using an information sheet submitted before the trials. An opening questionnaire established, amongst other things, their attitudes to computers and topographic maps. Two pre-tests were administered to assess their pre-intervention map use skills, one for map reading and the other for map analysis.

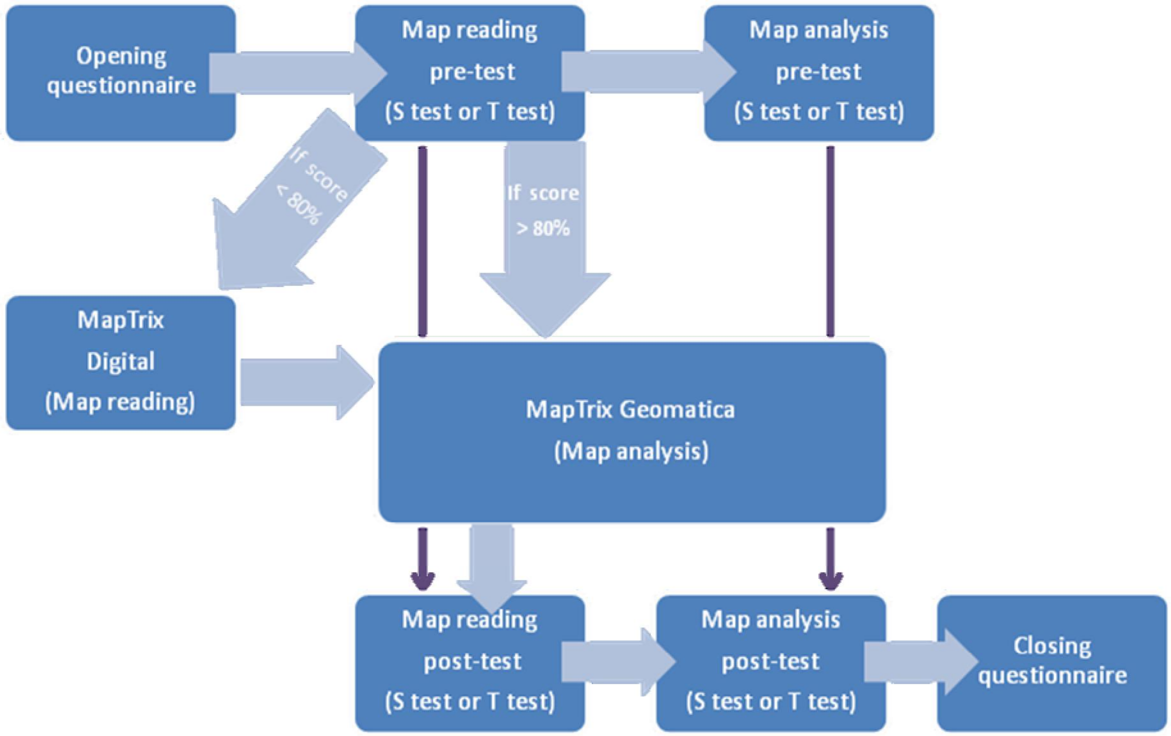


Figure 7.3 Administration procedure used for the first trials of the beta version of the MapTrix Digital Game and the MapTrix Geomatica prototype

At the end of the trial process, once both programmes had been completed, map reading and map analysis post-tests were written followed by completion of a closing questionnaire. The test instruments required almost as much care in development as the intervention instruments. To ensure the validity of the test-intervene-test method, two tests of equal difficulty were derived, named the S and T tests, and used alternately as pre- and post-tests. Without this precaution then an easy pre-test followed by a difficult post-test would reflect no improvement, while a difficult pre-test followed by an easy post-test would incorrectly suggest significant improvement. The data collection instruments used to gather information about the participants and their interaction with the intervention instruments are included in Appendices 8.1 to 8.5 and discussed at length in Chapter Eight.

7.5 THE MAPTRIX DIGITAL GAME

7.5.1 Background

The development of CBT (computer-based training) programmes in the sixties and seventies first highlighted the importance of identifying specific learning outcomes. These guidelines (Gagné and Briggs, 1974 and others) for developing CBT programmes were used to identify the outcomes required for a map reading programme. While the researcher's dream, in the eighties, was to develop a CBT programme for improving map reading at school level, very few South African schools had computer facilities at the time; CBT principles were used to design *MapTrix* but it was produced in the paper-based format.

Things have changed radically since the early history of *MapTrix* – technology itself and access to that technology as well as the South African curriculum and education policy. The local province, the Western Cape, has moved forward rapidly to implement new policies. The Khanya Project of the Western Cape Education Department (WCED) is rapidly equipping all high schools with at least one computer laboratory. Mathematics education has also benefitted enormously from a private sector/public sector partnership to place mathematics teaching programmes into these laboratories (Khanya, 2005; Matandela, 2008).

Rapid growth, in the computer graphics industry, led to the transformation of the production process of the South African national map series. Symbols on the 1:50 000 topographic map series were adapted in the late eighties to accommodate digital production changes. These initially caused much confusion among geography teachers because the slow pace of updating meant that there were sheets with differing symbols in circulation (Innes, 1995). A rapid capture project initiated in the early nineties resulted in the availability of digital data in vector and raster formats for the entire 1:50 000 topographic map series as well as orthophoto maps and various other spatial information products (DLA, 2000). The pricing policy of this invaluable national asset makes digital data available at no cost to a growing GIS industry which updates and corrects (where necessary) and then adapts the base map series for a variety of purposes.

Despite favourable feedback from a national teacher survey (Chapter Three), it was always recognised that *MapTrix* was limited to topographic map reading only. When looking for a way to develop a map analysis programme to teach the middle order map analysis skills it was decided to build on the existing *MapTrix* programme. One of the reasons that self-instruction was chosen as a methodology for improving map reading was that many teachers lacked the training to teach topographic map use (as discussed in Chapter Six). Not all those who teach Geography have received training in the subject. In many cases the training received has not met the requirements of learners needing guidance to read, analyse and interpret topographic maps at matriculation level. It was felt that a self-instruction programme would supply the resources for learners as well as an opportunity for teachers to improve their own competence.

With the introduction of GIS into the geography curriculum it became imperative to introduce an IT component to the learning environment. Self-instruction once again appeals as a means to up-skill teachers while simultaneously giving learners the opportunity to develop their map analysis skills and, concurrently, learn about and through IT.

7.5.2 Conversion of *MapTrix* to the MapTrix Digital Game

Eltanin Training Academy (formerly Quality Training Technologies) develops flight simulators and trains pilots and navigators for both civil and military aviation requirements. Two specific training needs had been identified for their clients' entry-level personnel: map reading and basic computer skills. The company had been introduced to *MapTrix* by a consultant, also working in the military training environment. She suggested that the digital conversion of *MapTrix* would address both these training challenges.

A computer based training (CBT) programme generally consists of all the learning material including lessons and evaluation procedures (exercises) plus a monitoring and assessment reporting protocol. An initial attempt to convert *MapTrix* to a full CBT programme on compact disc (CD) ran into difficulties due to the large file sizes of all the maps and full-colour symbol explanations. These left little space on a CD for the software required to keep records of each learner who logs onto the learning programme. This proved too programme intensive and it was decided that a downloadable scorecard would be included that could be printed out and progress would be monitored manually (Appendix 7.1). The MapTrix Digital Game is not, therefore, a fully-fledged computer based training programme but is better described as a computer assisted training (CAT) programme for revising map reading.

In the agreement concluded with Eltanin Training Academy to convert *MapTrix* into a CAT programme, the text copyright is retained by the author, the programming rights retained by Eltanin and the copyright on the maps and photographs retained by the NMO. As part of the agreement, the

NMO supplied the map extracts that had been prepared for *MapTrix* to Eltanin as high resolution raster data along with the accompanying alphanumeric grids. Government Printer's copyright authority has been granted to use the map extracts. High resolution scans of the backs of the *MapTrix* work cards, showing the illustrated symbol explanations, were also supplied as digital files. Each symbol explanation was imported individually and arranged alphabetically for inter-active screen access from the map key while using the learning programme.

While the process had taken a number of years to complete, a beta version of the MapTrix Digital Game was available at the commencement of the MapTrix Geomatica trials and was used to good effect in introducing novice computer users to the keyboard to play the Game while simultaneously improving their map reading skills (as reported in the next chapter).

The purpose of the MapTrix Digital Game is the revision of map reading skills that have already been learned in the classroom (whether using *MapTrix* or any other methodology) or, preferably, outside the classroom with the local topographic map. This computer-assisted map reading revision game provides 52 topographic map extracts organised into four geographic concept learning areas; rural settlement (hearts), urban settlement (clubs), transport (diamonds) and landscape (spades). Each learning area is represented by a different playing card suite (as indicated in brackets). Learners progress through the game by answering ten multiple choice questions on selected map extracts.

The opening screen displays the full deck of playing cards and players select any card to start play. The objective is to score at least eight out of ten correct answers on at least 12 cards - one each of an odd number, even number and picture card in each of four suites (12 x 8) giving a minimum score of 96 points to indicate mastery of the game. The ultimate goal is to complete all four suits by playing only 12 cards in total, getting all the answers correct, and earning the highest possible score of 120 points in the shortest time. The game can be played solitaire or players can challenge each other.

Scaffolding (learner support material) is provided in the form of concept lessons, descriptions of the map area and illustrated symbol explanations. The relevant lesson can be opened and read once the player selects a playing card from one of the four suites. The description of the area can be opened once the map appears on screen. An interactive reference list (the map key) appears down the side of the screen while the map extract is open. A total of 96 different map symbols and words appear on the national topographic map. The name of each one with the symbol is listed alphabetically.

The player scrolls to the symbol they want to find out more about, clicks it and an explanation of the symbol accompanied by a full colour photograph opens on screen.

Each question appears individually below the map with the optional answers. Players select their preferred answer. Only one answer chance is provided, assessed as keyed in and marked ü or û. When all ten questions have been attempted a score screen appears with the results giving immediate feedback. Players transfer their results manually to their scorecards (Appendix 7.1).

7.6 TRIALING THE INTERVENTION INSTRUMENTS

7.6.1 Securing a venue and staff to assist with the trials

Two prototype intervention instruments were ready for assessment: the MapTrix Digital Game for improving map reading performance and MapTrix Geomatica for improving map analysis performance. A venue for running the trials was secured: a computer laboratory with approximately eighty computer terminals in the R.W. James Building on the campus of the University of Cape Town (UCT). The facility was booked from 2 July to 12 July 2007 during the mid-year vacations. Volunteer staff who agreed to assist at the trials included an experienced geography teacher who has a particular interest in practical map use and a technical expert seconded by Naperian GIS Technologies who is also the IT manager of the GIS Department at the University of Fort Hare. The next challenge was finding participants to trial the two intervention instruments.

7.6.2 Strategies for securing participants for the first trial

It was decided to advertise the trial as a free Topographic Map Analysis Course to be offered during the mid-year school holidays. Six hundred advertising leaflets (Appendix 7.2) were prepared for distribution to potential participants. Based on an average market return of 10 % this would hopefully secure approximately 60 trial participants. Because the interventions were designed for school based learners, it was decided that the majority of trial participants should still be at school. The initial plan was to distribute the leaflets directly to schools in the vicinity of the university. The profile of a preferred volunteer was a participant with an interest in Geography and, within that discipline, a particular interest in map use. If possible, he or she should also be interested in GIS. Two opportunities arose to distribute the leaflets to a population sample close to the preferred profile. The University of Cape Town (UCT) Open Day in May 2007 and GIS Week 2007 at the University of the Western Cape (UWC) later the same month.

- UCT Open Day 2007

The annual Open Day is broadly advertised to learners in their final year of schooling as an opportunity to come and see what the University offers. Advertising leaflets were handed to potential students who visited the stand of the Department of Environmental and Geographical Science. Following the Open Day, a poster was placed on the departmental notice board advertising the Topographic Map Analysis Course and leaflets were placed below the advert for collection by students who were already taking Geography. Participant information forms were lodged with the departmental secretary who agreed to collect completed forms.

- GIS Week 2007

Since 2006 an annual GIS Week has been hosted by the University of the Western Cape (UWC) to promote GIS in schools. The event has been arranged by the Chief Directorate of Surveys and Mapping (CDSM) and the Geographic Information Society of South Africa (GISSA) in collaboration with the Western Cape Education Department.

Schools reserve time slots of two hours each to bring geography learners in groups of 40 to 50 to the event. Each group is first introduced to GIS using an illustrated address and video. They then proceed into a computer laboratory where they share terminals and are introduced to a practical activity using GIS software. Afterwards they visit the exhibition area where a range of GIS users demonstrate various applications, provide hand-outs, offer career guidance and generally try to make the learners enthusiastic about GIS. Groups follow each other through the venues at half-hour intervals.

During GIS Week 2007, at the MapTrix Services (www.maptrix.co.za) exhibition stand, 23 local high school geography teachers were interviewed and contact details noted. They were informed of the research being undertaken to prepare an advanced version of the *MapTrix Kit*, which many were already using at their schools, and encouraged to promote the Topographic Map Analysis Course being offered in the holidays. They encouraged learners accompanying them to take leaflets and all agreed to distribute more amongst the learners who had not come to the exhibition. Participant information forms were made available to all teachers and to individual learners who showed an interest. Faxes were sent to the teachers during the following week to thank them for their interest and to remind them to promote the course amongst their learners.

Unfortunately, in the period between GIS Week and the school holidays, a national strike by civil servants severely disrupted schooling for a period of some weeks (Weekend Post, 2007). Many schools in the highly politicised areas from where learners had been bussed to the GIS Week exhibition were closed down by strike action. In more affluent areas closer to the city, some schools remained open with reduced staff numbers and managed to maintain some form of teaching and learning.

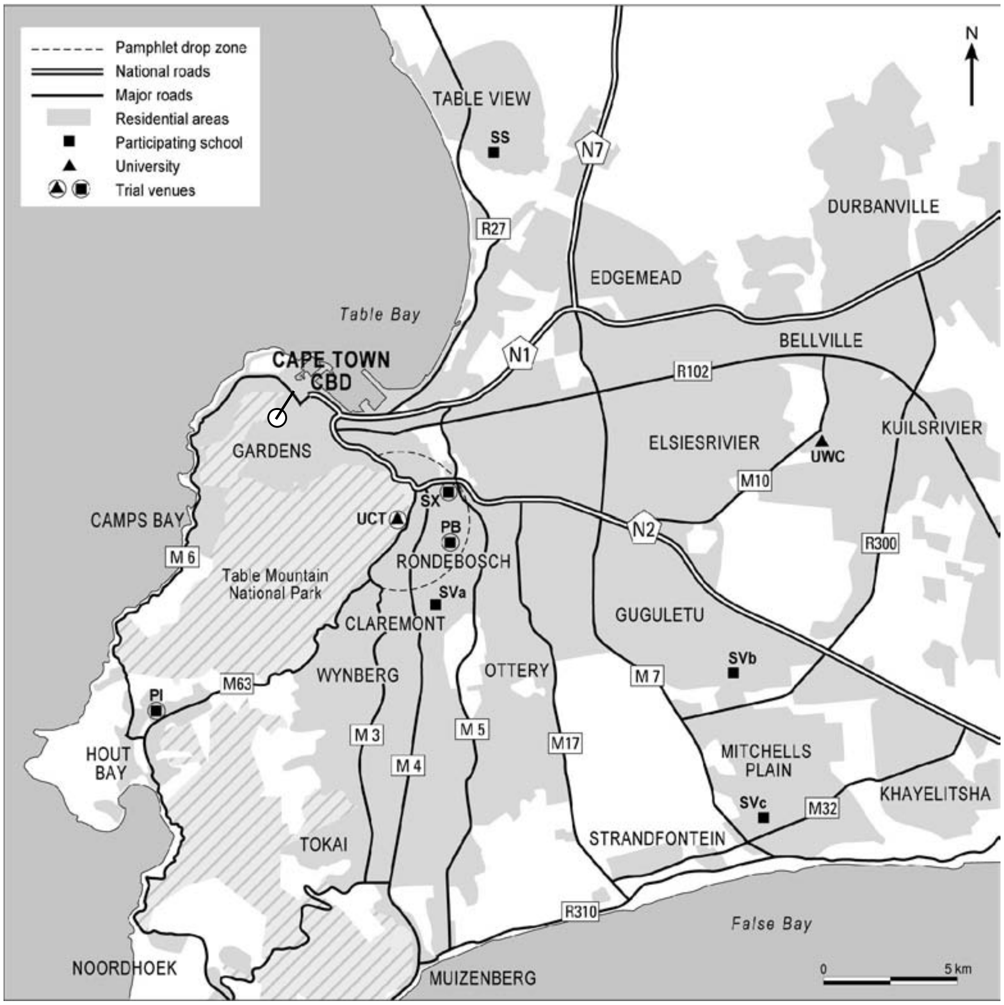


Figure 7.4 Map showing venues and the schools attended by the participants in the MapTrix Geomatica and MapTrix Digital Game trials

- Invitations delivered to local schools

There was only one response from the UCT Open Day. As the time for the trials drew closer it became clear that the expected participation of learners from schools who had attended GIS Week would not materialise. It was feared that the small number of respondents may be insufficient to produce a large enough trial population sample. In keeping with the original plan, local schools were hastily invited. With the post office on the UCT campus at the centre of a circle, arcs were drawn at 1 km, 1,5 km, 2 km and 2,5 km until a total of 12 local high schools were identified within easy reach of the campus (Figure 7.4).

Each school was telephoned to establish whether they were operating despite the strike; two were not open due to strike action and one had closed early for the school holidays. The name of the Head of Department for Geography was requested; where available, some were interviewed telephonically, others in person. An information pamphlet was compiled giving details of the research project. This was packaged with a number of the advertising leaflets and copies of the participant information forms and they were hand delivered to the schools that had been identified in the pamphlet drop zone in Figure 7.4.

7.6.3 First trial population

Table 7.2 Results of different strategies for securing participants for the first trial of MapTrix Geomatica, showing the level of their participation

Trial participation	**Schools that formed Group SV**												**Group SV total**			**Group SS total**			**First trial totals**		
	School a			**School b**			**School c**			**Other schools**											
	M	F	n	M	F	n	M	F	n	M	F	n	M	F	n	M	F	n	M	F	Σ
Completed course	1	6									1		1	10		6	3		7	13	20
Almost completed course				1									1				2		1	2	3
Both pre- and post-tests	1	6	7	1	0	1	0	0	0	0	1	1	2	10	**12**	6	5	**11**	**8**	**15**	**23**
Pre-tests only, left after 1 day		2						2						4		2			2	4	6
Pre-tests only, left after 2 days		1												1					0	1	1
Pre-tests only, left after 3 days		1					1						1	1					1	1	2
Pre-test only	0	4	4	0	0	0	1	2	3	0	0	0	1	6	**7**	2	0	**2**	**3**	**6**	**9**
Booked, no show	2	13								2			4	13		2	2		6	15	21
Enquiry only					1					1			1	1					1	1	2
Let downs	2	13	15	0	1	1	0	0	0	3	0	3	5	14	19	2	2	4	7	16	23
Responses from schools	3	23	26	1	1	2	1	2	3	3	1	4	8	30	**38**	10	7	**17**	18	37	**55**

M = male, F = female; n = number per Group; Σ = Total number of participant responses for First trial

	Full participation, data gathered from all instruments		Pre-test scores used to validate equal difficulty of S and T tests		No data could be gathered

One of the teachers interviewed during GIS Week made good the undertaking to promote the course among learners at School **a** (see Table 7.2). He arranged to have the participant information forms completed, signed by learners and their parents and faxed back. Although 26 learners completed participant information forms and were booked to attend, unfortunately only 11 arrived of which 7 eventually completed the course. From School **b** two learners made enquiries of which one eventually completed the course. Three individuals arrived from School **c** of which two never returned after the first day and the other failed to complete the programme.

Individuals from other schools joined the group; their school names were not provided on their participant information forms but it was assumed that their attendance was the result of the pamphlets distributed just before the schools closed (see Figure 7.4). Because they were from various state schools the group was later identified as Group SV. Three adult learners joined the group, two teachers from state schools and a Masters Degree student in the Department of Geographical and Environmental Science at UCT.

A teacher from another state school who had attended GIS Week with her pupils, arranged transport and brought a group into the city from Table View (see map in Figure 7.4) during the second week of the trials. Because they were a relatively large group from a single state school they were identified as Group SS. Originally 20 participant information forms were received but in the end only 14 completed the course.

7.7 IMPLEMENTATION AND ADMINISTRATION OF THE TRIAL PROCESS

7.7.1 First trial by volunteers at UCT

In total, 55 people responded to advertisements for a Free Topographic Map Analysis Course, approximating the 10 % envisaged from 600 advertising leaflets (Appendix 7.2). As indicated in Table 7.2, 23 individuals never followed through leaving 32 who actually arrived to trial the learning programmes. Of these, 23 participated fully in the first trials and the results of a further nine participants were used for part of the assessment process. The trials ran for nine week days from 2nd to 12th July 2007. Participants with completed information sheets (Appendix 8.1) were invited to complete the opening questionnaire (Appendix 8.2), write the map reading (Appendix 8.3) and map analysis (Appendix 8.4) pre-tests and start the course on Monday 2nd July, Wednesday

4th July or Monday 9th July. Most members of Group SV started during the first week while Group SS started in the second week.

While the main focus of the trial was the evaluation of the map analysis programme, there were two reasons for setting pre- and post-tests for map reading. First was to ensure that participants' map reading skills were adequate to proceed to the map analysis programme. Second was to validate that the two tests alternated as pre- and post-tests were equally difficult so that they could be used to evaluate the map reading intervention. Only those candidates who scored 80 % and above (12 correct answers or more out of 15) went straight onto the map analysis course; those who scored less than 80 % were offered the MapTrix Digital Game in an attempt to improve their map reading performance. They were moved to a bank of terminals near the rear of the room and supervised by a research assistant. Their progress was observed and once they were making good progress and attaining mastery scores (80 % correct answers) they were moved on to the map analysis programme. Once participants had completed the map analysis programme they sat post-tests to assess their scores for both map reading and map analysis, following which a closing questionnaire was completed (Figure 7.3).

In hindsight, the relatively small number who participated in the first trial was probably a blessing in disguise as running the two intervention programmes side-by-side proved far more difficult than was at first anticipated, despite the help of two research assistants. The first four participants who started on Monday 2nd July were treated as a pilot study group and provided valuable insights into the administration of the evaluation process, particularly in terms of the additional materials that had to be prepared beforehand (e.g. photocopying of answer sheets), the audio equipment that was required (earphones for the sound inserts) as well as equipment for completing the map analysis tasks manually (e.g. rulers, setsquares and full circle protractors). By the time more members of Group SV started later in the week, some of the initial snags had been ironed out, a filing system for participant responses had been established and the questionnaires had been tested by using them as the basis of face to face interviews.

During the trials, the technical expert was able to elaborate on the intricacies of the GIS software and explain to those technologically advanced young learners who enquired about the operating systems, aspects of the programming that had previously been beyond the comprehension of the technologically less-advanced researcher.

7.7.2 Time taken to complete the map analysis programme

Time available and time taken to complete the map analysis programme varied considerably depending on individual participants and the circumstances under which the trials were conducted. Both the time available and the time taken were noted in hours or part thereof. Because time available varied significantly and may have an impact on the outcome of the trial, it was detailed per Group.

- Group SV

Time available for Group SV was potentially 40 hours (Table 7.3). Once they had been introduced to the programme participants were free to use the venue for as many sessions as they needed. They could select all or some of the three two-hour sessions offered on most days. Potentially a learner starting on the first day could take as many as 40 hours to complete one or both programmes if required.

Table 7.3 Trial timetable for Group SV - MapTrix Digital Game and MapTrix Geomatica

Number of sessions per day	Duration of sessions	Minutes	Hours
Day 1 – Orientation only			
Day 2 – 3 sessions	120 minutes	360	6
Day 3 – 3 sessions	120 minutes	360	6
Day 4 – 3 sessions	120 minutes	360	6
Day 5 – 1 session	120 minutes	120	2
Day 6 – 3 sessions	120 minutes	360	6
Day 7 – 3 sessions	120 minutes	360	6
Day 8 – 3 sessions	120 minutes	360	6
Day 9 – 1 session (followed by post-tests and closing questionnaire)	120 minutes	120	2
Total time available			40 hours

Time taken by individual members of Group SV to complete the map analysis programme was derived from an attendance register kept for each participant. One two-hour session was occupied with the pre-testing, completion of questionnaires and introduction to MapTrix Geomatica. For most of those who required the MapTrix Digital Game, a further two-hour session was set aside. Their progress was closely monitored. Some required a further hour or two of map reading practice before being introduced to MapTrix Geomatica. At the end of the trial, another two-hour session was devoted to the post-tests, closing questionnaire and discussion. The time data entered represents the number of hours spent working through the lessons, answering the questions and then marking the answers of the map analysis programme.

- Group SS

Time available for Group SS was limited to twelve hours (Table 7.4). Learners were bussed in by teachers from the school on 9, 10 and 11 July 2007. Only two days of transport were initially arranged but the accompanying teacher agreed to bring learners who had not completed the programme into the city on the third day until lunchtime. The limited time meant that a few participants did not complete all the lessons and exercises but all agreed to complete the post-tests and closing questionnaire.

Table 7.4 Trial timetable for Group SS – MapTrix Digital Game and MapTrix Geomatica

Number of sessions per day	**Duration of sessions**	**Minutes**	**Hours**
Day 1 – Orientation plus 2 sessions	120 minutes	240	4
Day 2 – 3 sessions	120 minutes	360	6
Day 3 – 1 session (followed by post-tests and questionnaire)	120 minutes	120	2
Total time available			12 hours

Time taken by Group SS on the MapTrix Geomatica programme was later calculated from the total time available (excluding pre- and post-tests and questionnaires) minus time spent on improving map reading skills using MapTrix Digital. Times were recorded to the nearest hour or part thereof.

7.7.3 Second and subsequent school-based trials

Rather than wait until the September holidays at the end of the third school term to run another holiday trial with volunteers, it was decided to try and arrange school-based trials. After the school vacations, further trial venues and participants were sought in the Cape Town area. The first school based trial with Group SX was run at a school within the 2.5 km pamphlet drop zone as illustrated in Figure 7.4. The details of how the arrangements were made, information about the school and its computer facilities, the staff who assisted and how the trial was implemented can be found in Appendix 7.3.

While the MapTrix Digital Game had been used in the first trial, the map reading post-tests had been written after participants had used both intervention instruments. This meant that the improved map reading results could not be ascribed exclusively to the MapTrix Digital Game. The opportunity to work with Group SX solved this problem and made it possible to evaluate the MapTrix Digital Game in isolation (see Figure 7.5). As circumstances, described in Appendix 7.3, dictated there was insufficient time to trial both map skills programmes within the confines of the school timetable and in the relatively short period of time at the school before it closed at the end of the third term.

Because of the time pressure it was decided that any further trials would have to be at schools where learners were already proficient map readers so that only the map analysis programme would be trialled. The private boys' school within the pamphlet drop zone (designated as Group PB on the map in Figure 7.4) was approached and a school-based trial was arranged. Participants followed the programme during timetabled lessons; full details are given in Appendix 7.4. In the last days of the final school term a private international school (Group PI in Hout Bay on the map in Figure 7.4) offered the opportunity to trial MapTrix Geomatica in a two-day intensive workshop setting; full details are given in Appendix 7.5.

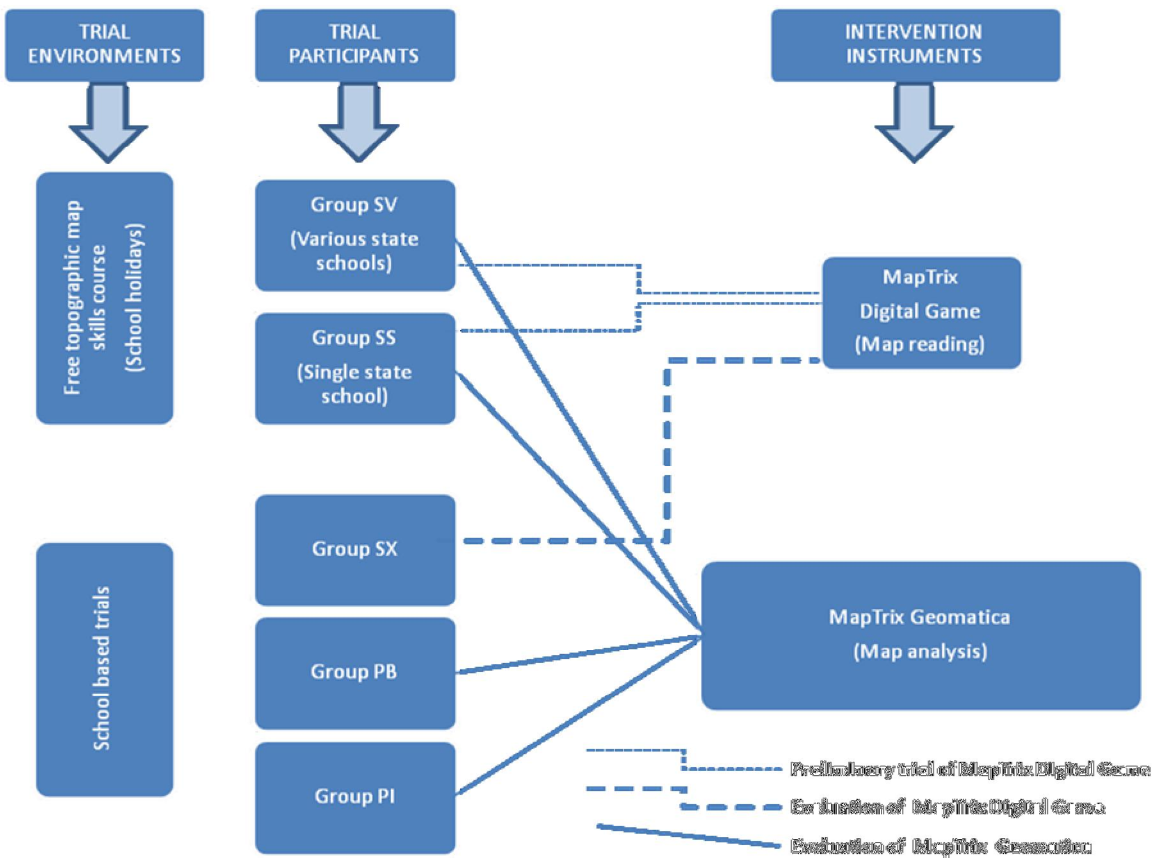


Figure 7.5 Five different Groups trialled the two map skills intervention instruments under two different types of trial environment

The data from the first trial at UCT with Groups SV and SS were combined with the data from Groups PB and PI and used to evaluate MapTrix Geomatica (Figure 7.5). The data from Group SX was used to evaluate the MapTrix Digital Game.

7.8 CONCLUSION

The central argument of the thesis, that self-instruction can be used to improve map analysis skills, depends on attaining the main research goal which is the development of a prototype self instruction programme as described in this chapter. The realisation of the MapTrix Geomatica prototype supports the hypothesis (described in 7.1.3) that such a programme can be developed and that it can be delivered on a GIS platform.

It was shown in the design phase of the project (illustrated in Figure P.1) that the ability to analyse spatial information requires the pre-requisite skill of map reading. The digital conversion of *MapTrix*, which is used to prepare participants for the trial of MapTrix Geomatica has been described, concluding the development phase of the project. Plans are in place for the evaluation of the MapTrix Geomatica prototype which will test the central hypothesis of the thesis that measurable improvements in map analysis performance can be attained by the use of such a programme.

CHAPTER 8
EVALUATION OF THE MAPTRIX DIGITAL GAME

"Now that I know about the map, I can take visual ownership of my place."
Response of an anonymous South African land claimant
after a MapAware Workshop circa 1998

8.1 INTRODUCTION

In Chapter Seven the development of the two intervention instruments, the MapTrix Digital Game (for map reading) and MapTrix Geomatica (for map analysis) was discussed and the trial strategy outlined. After a brief discussion of the instruments used to collect the trial data in this introduction, this chapter focuses on the MapTrix Digital Game.

Figure 7.5 illustrates which groups participated in the trials of the two intervention prototypes and Table 8.1 briefly summaries the group particulars, the incentives used to secure their participation and the dates of the trials. Conditions under which the holiday volunteers, Groups SV and SS, first trialled the self-instruction programmes, are described in Chapter Seven (7.7). Details of the school-based trials can be found in Appendix 7.3 (Group SX), Appendix 7.4 (Group PB) and Appendix 7.5 (Group PI). Ethical principals were adhered to throughout. Prior to their participation in the trials, parental permission for all participants under the age of 18 years was obtained (see closing section of Appendix 8.1). During the trials, participant names were used on all instruments to facilitate collation of their data, but confidentiality was assured by allocating participant codes which were then used when tabulating the data. Permission for Group SX to participate in the trials was granted by the WCED under strict confidentiality conditions which prohibited disclosure of the names of the school, teachers or learners. In keeping with these ethical considerations, the details of the other school-based trial participants are not disclosed either.

Table 8.1 Chronological summary of the different groups that trialled the MapTrix Digital Game (map reading intervention) and MapTrix Geomatica (map analysis intervention)

Group code* (n)	**Group particulars**	**Incentive**
(2 to 12 July 2007) **SV** (19)	Mixed group of volunteers from various state schools, including learners in Grades 10, 11 and 12 and three adult learners, attended a map skills course in a computer laboratory at the University of Cape Town during the mid-year vacation. Participants selected as many daily 2-hour computer sessions as required (maximum of three sessions per day). Both the **map reading and map analysis programmes** were offered (see Chapter 7.7).	Free Topographic Map Analysis Course offered during school holidays
(9 to 11 July 2007) **SS** (13)	Grade 10, 11 and 12 learners from a single state school were bussed to the University of Cape Town during the school holidays for an intensive two and a half day map skills workshop in the computer laboratory. Both the **map reading and the map analysis programmes** were offered (see Chapter 7.7).	Free Topographic Map Analysis Course offered during school holidays
(3 to 20 September 2007) **SX** (64)	Learners in two Grade 10 classes at a state school were initially offered both map skills programmes in the computer laboratory at the school during timetabled class periods. The available time was taken up with using the **map reading programme**. Unfortunately there was not enough time for the map analysis programme (see Appendix 7.3).	Opportunity to improve map skills plus IT lab alternative to conventional classroom lessons; three prizes offered for good performance
(15 to 26 October 2007) **PB** (19)	One class of Grade ten learners at a private boys' school was offered the **map analysis programme**. It was loaded onto their personal laptops and used during timetabled class periods. They were also required to complete some of the exercises during their preparation (homework) time (see appendix 7.4).	End of year geography examination preparation; prize offered for best performance
(27 to 30 November 2007) **PI** (12)	Learners at a private international co-educational school trialled the **map analysis programme** in a two-day intensive workshop in the science laboratory. Pre- and post-tests were conducted outside the work-shop timeframe. They used laptops assigned to them for their personal use on the school premises (see Appendix 7.5).	Opportunity to participate in active research and to learn new software (GIS) during an end of term activity programme; cake and sweets provided.

*Key to letter codes used for the trial groups, based on the types of schools that they attended

Administration	**Code**	**Description**
State schools S	SV	Various state schools (holiday volunteers)
	SS	Single state school (holiday volunteers)
	SX	State school
Private schools P	PB	Private boys school
	PI	Private international school

The data collection instruments have been listed in the approximate order in which they were used during the trial process as illustrated in Figure 7.3:

- Participant information sheet – Appendix 8.1
- Opening questionnaire – Appendix 8.2
- Map reading S and T tests used alternately as pre- and post-tests (and accompanying map) – Appendix 8.3
- Map analysis S and T tests used alternately as pre- and post-tests – Appendix 8.4
- MapTrix Geomatica exercise and answer sheets – example in Appendix 8.5
- Closing questionnaire – Appendix 8.6

The strategies used to code and gather the data from the instruments in Appendices 8.1 to 8.6 are outlined in Appendix 8.8. Following the trials, the quantitative data were compiled into a table (Excel spreadsheet) showing the 127 individual participants against 184 columns of variables.

Interval scales were used extensively (e.g. raw scores for pre-tests and post-tests). Much of the qualitative data were converted to nominal scales (e.g. Male = 1, Female = 2) and ordinal scales (e.g. years of schooling) so that comparisons between variables could be made (Ebdon, 1985). While the data were used for the evaluation of both map skills interventions described in the previous chapter, only the evaluation of the MapTrix Digital Game for topographic map reading is reported here.

8.2 TRIAL OF THE MAPTRIX DIGITAL GAME

8.2.1 Hypothesis for the trial within a trial

The hypothesis is that playing the MapTrix Digital Game will lead to measurable improvements in map reading scores using the test-intervention-test evaluation methodology.

Once participants in the first trials (Groups SV and SS) had completed the map reading pre-tests (Appendix 8.3), their answers were assessed by the research assistants to ascertain whether they had scored over 80 % to progress to the map analysis programme (Figure 7.3). If their scores were less than 80 % indicating that they were not yet proficient map readers, participants were offered the MapTrix Digital Game, described in Chapter Seven (7.5), to improve their map reading skills. Their progress was monitored and once their exercise scores consistently reached 80 %, they were moved to the map analysis programme. Only after they had completed MapTrix Geomatica was a map reading post-test administered.

Naturally, the second intervention programme offered participants the opportunity for additional map reading practice (while identifying features and locating information to answer the map analysis questions). Any difference between their map reading pre- and post-test scores could not be attributed solely to the MapTrix Digital Game. However, by playing the MapTrix Digital Game, they had participated in a qualitative evaluation of the conversion of the one-word answers of the *MapTrix* original to the multiple choice answer format of MapTrix Digital.

When their map reading exercise scores on the MapTrix Digital Game scorecards (Appendix 7.1) were assessed against the answers on screen, a number of errors were identified in both data input and in the programming of the automatic answer scoring system for 19 of the 52 cards in the pack. This pilot evaluation of the MapTrix Digital Game by Groups SV and SS identified 33 error-free, playing card linked, exercises. A selection sheet (Appendix 8.7) was prepared so that the next trial participants could be instructed to play only the error-free cards. As illustrated in Figure 7.5, Group SX formed the population sample that evaluated the MapTrix Digital Game. Their full details are given in Appendix 7.3.

8.2.2 Materials and method

Once the two classes of Grade 10 learners in Group SX had completed the personal information forms (Appendix 8.1) and opening questionnaires (Appendix 8.2), they wrote the pre-tests for map reading (Appendix 8.3) and map analysis (Appendix 8.4). The playing card structure of the MapTrix Digital Game was explained and they were given a scorecard (Appendix 7.1) and a card selection sheet (Appendix 8.7). At the terminals in the computer laboratory game components were demonstrated, the links between screens illustrated and the rules of play explained. Participants were guided through a trial exercise and shown how to enter their score for each answer. They were also shown how to graph their scores. Once learners had selected their first playing card, they quickly learned to scroll around the map extract, open the illustrations of the map symbols and select what they considered were the right answers. Some, but not all, referred to the lessons and to the map information. Each time they selected a playing card on screen they were instructed to fill in the playing card suit and number. After completing each exercise they were to enter the results for each question presented on screen (1 = correct answer, 0 = incorrect answer), then add up the score and enter a total for the exercise.

8.2.3 Evaluating the test instruments - map reading S and T tests

The test – intervene – test method described in Chapter Seven (7.4) was used to evaluate the MapTrix Digital Game. Before evaluating the programme by comparing the pre- and post test scores, the test instruments themselves had to be evaluated to ensure that the two tests were of equal difficulty. Two banks of map reading tests had been derived when the original prototype of *MapTrix* was evaluated (Innes, 1998). These tests were later adapted for assessing a series of MapAware Workshops run by the Chief Directorate of Surveys and Mapping (Innes and Engel, 2003). The same map reading tests were adapted slightly once again and named the map reading S test and the map reading T test (Appendix 8.3). Each consisted of 15 questions that required participants to identify map symbols. They were matched so that references to point, line and area symbols were equally represented. Questions were based on the MapAware Test Map, a topographic-style map created for the style chart of the standard 1:50 000 topographic map of South

Africa (CDSM, 2000). Multiple-choice answers were provided on the test sheet, which consisted of one correct answer and three distracters. Each correct answer equals one point. The two tests were distributed alternately as pre-tests before the intervention started.

To evaluate test equivalence, data from the first trial at UCT with Groups SV and SS and the first school-based trial with Group SX were combined to form a single dataset. The means and standard deviations of the map reading S and T test scores and times were calculated. Student's t test was used to check whether the two banks of questions used as both pre- and post-tests were of equal difficulty (i.e. to test the null hypothesis that there was no significant difference between the datasets or to reject the null hypothesis if a significant difference was found). The results are summarised in Table 8.2.

Table 8.2 Comparing score and time to establish the equivalent difficulty of map reading S and T tests when used alternately as pre- or post-tests

Map reading evaluation	S Test	T Test	Probability of significant difference
Pre-test - mean score (/15) ± SD	9.87 ± 3.02 (n = 61)	9.68 ± 3.47 (n = 60)	25 % ns
Post-test - mean score (/15) ± SD	12.11 ± 2.64 (n = 47)	11.31 ± 3.03 (n = 48)	82 % ns
Pre-test - mean time (in minutes) ± SD	11.70 ± 3.22 (n = 61)	11.33 ± 2.81 (n = 60)	49 % ns
Post-test - mean time (in minutes) ± SD	9.91 ± 3.23 (n = 47)	10.71 ± 2.77 (n = 48)	80 % ns

ns = not significantly different (at p = 95%)

The difference in mean score of 0.19/15 between the S and T tests when used as pre-tests was not significant (p = 95%, n = 121). Unfortunately not all those who wrote the pre-test completed the programme and sat the post-test. However, Student's t test still confirmed that the difference of 0.8/15 between the mean scores of those who sat the S and T tests as post-tests was not significantly different (p = 95%, n = 94).

Time taken to complete the map reading tests was used as a further validation of the equivalence of the two banks of questions in the S and T tests. The small differences in the times taken to complete the S and T tests (0.37 minutes on pre-test and 0.8 minutes on the post-test) were also not statistically significant. The chance of bias in the assessment instrument was thus eliminated by using two equivalent tests alternately as pre- and post-tests.

8.3 RESULTS

8.3.1 Map reading pre-tests

The map reading pre-tests were assessed immediately after the first period with each class. The results indicated that, although a small minority in the smaller class and about a quarter of the learners in the larger class were already competent map readers, there were many learners whose map reading skills were extremely weak (see Figures 8.4 and 8.5). With such a wide disparity between the best and worst map readers it was decided to try and improve the basic skills of the majority of learners in both groups before moving any of them to the GIS-based map analysis programme.

8.3.2 Map analysis pre-tests

When the trials with Group SX started it was assumed that both map skills interventions would be offered. The first indication that this might not be possible was the low mean score for map reading. The results of the map analysis pre-tests served as a further warning. The amount of assistance with the map analysis intervention that would be required by the Group could be gauged from their average map analysis pre-test score of only 8.14 %.

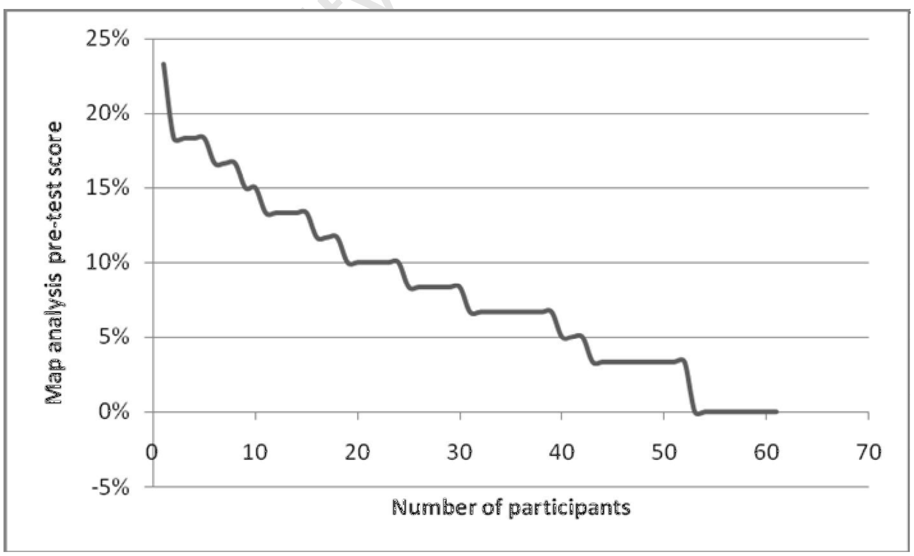


Figure 8.1 Ranked results of the 61 participants in Group SX who sat the map analysis pre-test

In Figure 8.1 the scores have been ranked and plotted to illustrate that they range from a maximum of 23 % attained by one learner down to 0 %, scored by 9 learners. It was clear that a large number of learners (initially working in two adjacent computer laboratories) would need assistance, both with map analysis concepts and with the GIS functionality of the learning programme. With no GIS-trained staff to assist the researcher, it was decided not to move the small cohort of proficient map readers up to the map analysis level. All learners were instructed to play a minimum of twelve cards in the MapTrix Digital Game (Appendix 8.7). This meant that the proficient map readers could be kept busy (improving their efficiency) while those with difficulties at this basic level had the opportunity to improve their map reading skills.

8.3.3 Comparison of pre- and post- test map reading scores

Of the total group of 67 Grade 10 learners who participated in the trial of the MapTrix Digital Game, the scores of only 45 could be used for the evaluation. The scores of 18 learners were invalidated because two were absent for both the pre- and post-tests and sixteen others were absent for the post-test (despite classes being given two opportunities to write the post-test). The overall results of the pre- and post- tests are represented in Figure 8.2.

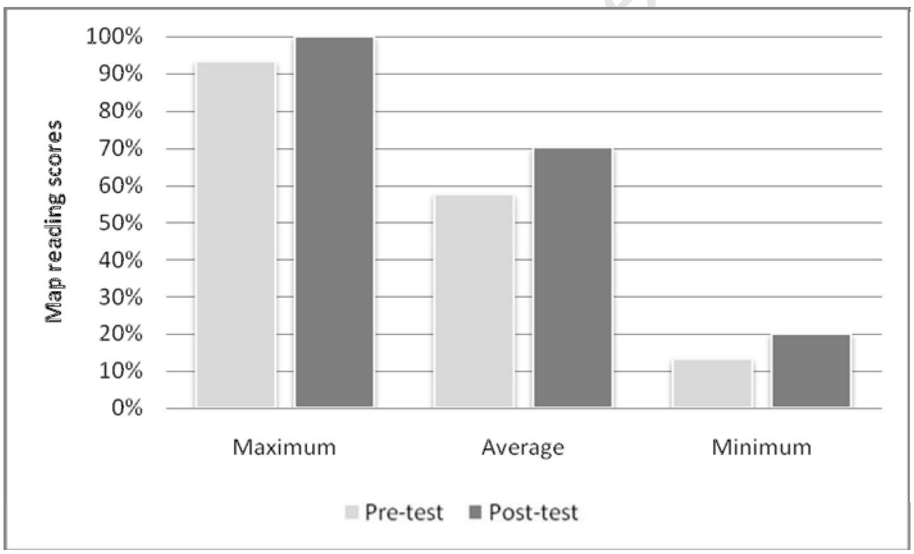


Figure 8.2 Map reading test results for all who trialled the MapTrix Digital Game and wrote both pre- and post-tests in Group SX (n = 45)

Differences between the pre- and post-test results plotted in Figure 8.2 suggest that the map reading programme contributed to the improved learners' scores at the maximum, mean and minimum levels, the mean scores improving by 12.6 % from 57.8 % to 70.4 %.

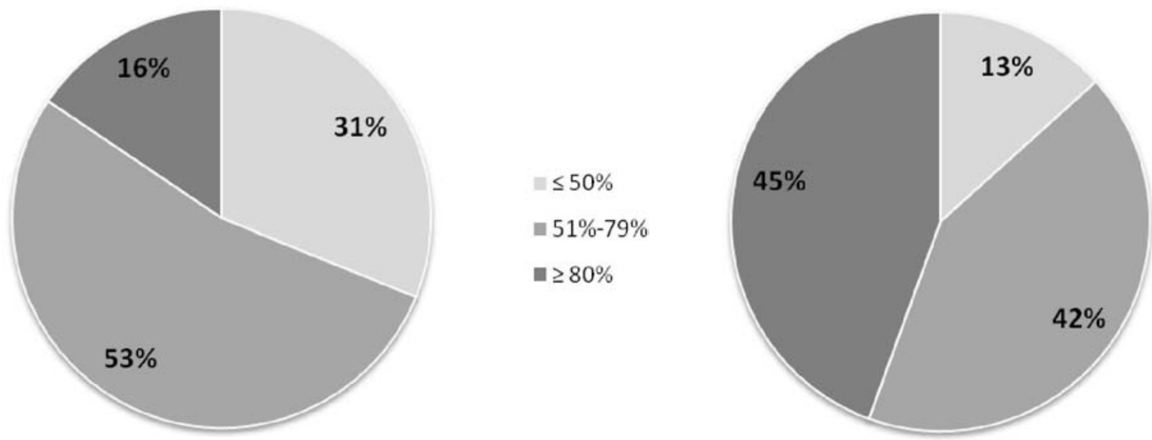


Figure 8.3 Breakdown of (left) the map reading pre-test scores and (right) the map reading post-test scores for all those in Group SX who trialled the MapTrix Digital Game

While Figure 8.2 shows encouraging results, the breakdown of scores in Figure 8.3 is more enlightening. Before the intervention, 31 % of learners attained poor scores, able to understand less than half the spatial information on a topographic map. Only 16 % of the group could have proceeded to the map analysis programme. After four lessons spent playing the MapTrix Digital Game, 45 % of the learners had mastered topographic map reading (gaining 80 % or more correct answers) and only 13 % were still attaining scores below 50 %.

8.3.4 Comparison of pre- and post-test scores per class

Figure 8.4 illustrates that, while half the learners in the small class showed a reasonable degree of map reading ability before the intervention, only 5% of them were already proficient map readers (scoring 80 % or more) while 45 % scored badly at the start of the trial. The post-test scores indicate that 35 % of learners had mastered map reading and the poor map readers had dropped to 20 % of the class.

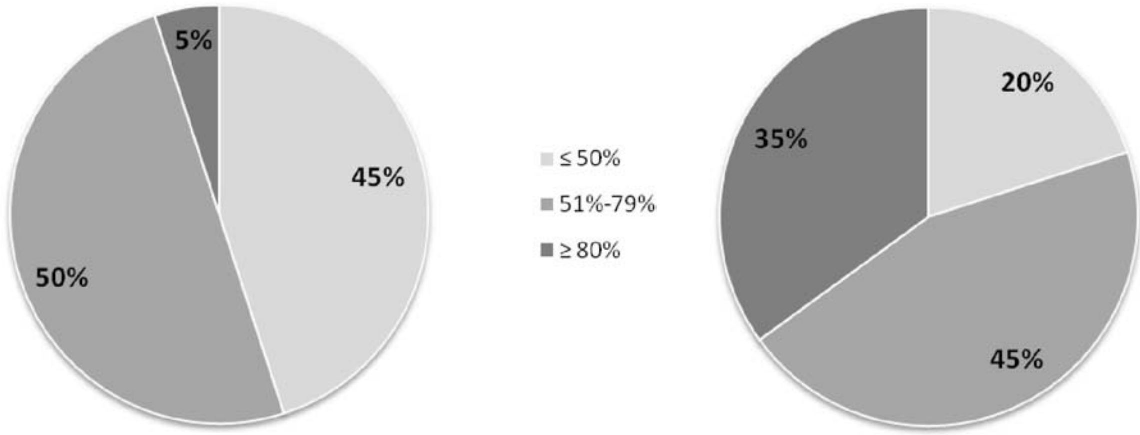


Figure 8.4 Breakdown of (left) the map reading pre-test scores and (right) the map reading post-test scores for the smaller of the classes in Group SX

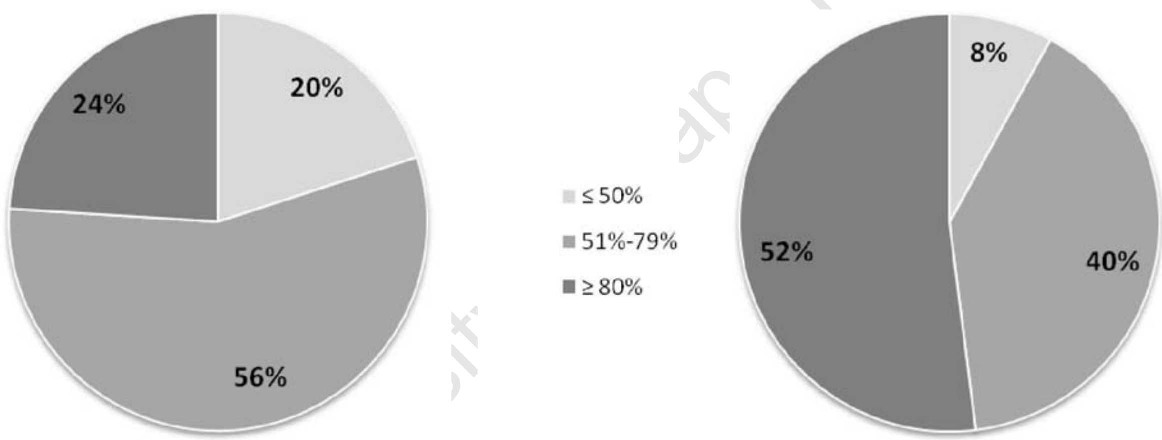


Figure 8.5 Breakdown of (left) the map reading pre-test scores and (right) the map reading post-test scores for the larger class in Group SX

Figure 8.5 shows that, in the larger class, 24 % of the learners could have proceeded straight on to the map analysis programme but it had been decided not to move them on because 20 % had very poor scores and more than half the class would not be able to read the maps with sufficient understanding to proceed confidently to the higher order skills programme.

8.4 DISCUSSION AND CONCLUSION

The Grade 10 learners who made up Group SX would all have moved up into the FET band by gaining acceptable grades at the end of the GET Band, in other words they would have passed

Grade 9 (Table 1.2). It is a matter of some concern that, despite the mapwork requirements of the compulsory Grade 9 Social Science Learning Area which include 'extracting, analysing and comparing information from maps' (DoE 2002:94), these learners were clearly under-prepared for map analysis tasks (as evidenced by their scores in Figure 8.1).

Before the new outcomes based curriculum for South African education was introduced (as discussed in Chapters One and Two), norm referenced assessment of learners set the pass mark for matriculation examinations as follows: Higher Grade – 40 %, Standard Grade – 35 %, Lower Grade – 30 %. One finding of the survey reported in Chapter Six (6.2.2) suggests that achieving a mere pass under poor working conditions, however low the benchmark, is considered adequate achievement. As in all subjects where concepts and skills have to be built up sequentially and consolidated before more advanced ones are introduced, inadequate preliminary preparation means that the majority of learners are unable to reach high performance standards because they are constantly disadvantaged by lack of foundational competence (Boardman, 1983 and following; Bennetts, 2002).

The assessment criteria introduced in the OBE system for FET are presently based on seven categories of performance (Table 8.3). Although a code of four on the rating scale may indicate *adequate achievement* in some areas, when it comes to competent map use, if learners are unable to read 40 % to 50 % of the map symbols, it is unlikely that they will be able to analyse efficiently the spatial information that is represented on the map. This is the reason for selecting ≤ 50 % as the category indicating poor map reading performance in Figures 8.3, 8.4 and 8.5. Likewise at the other end of the scale, it is only those who can read a map with the fewest errors that are considered to have mastered map reading, indicated by a score of ≥ 80 % or *outstanding achievement* according to the rating in Table 8.3.

Table 8.3 Rating codes related to marks as approved for the FET band (DoE, 2008b:5)

RATING CODE	RATING	MARKS %
7	Outstanding achievement	80 – 100
6	Meritorious achievement	70 – 79
5	Substantial achievement	60 – 69
4	Adequate achievement	50 – 59
3	Moderate achievement	40 – 49
2	Elementary achievement	30 – 39
1	Not achieved	0 -29

The map reading scores for the two classes (Figures 8.4 and 8.5) show evidence of a broad spectrum of spatial competence amongst the learners. This is a significant problem faced by many teachers of all subjects in South African classrooms but is particularly difficult to deal with for geography teachers when developing map use skills. While some learners have already mastered this vital geographical skill, and become bored with repetition of the same lessons, other learners need more opportunities to engage with maps and to practice their lower order map skills so that they can advance up the skills hierarchy. Of some concern are the 13 % of students in Group SX (Figure 8.3) who were still not able to read a topographic map with confidence after the intervention with the MapTrix Digital Game. While further investigations of the results are not reported here, because the focus of the thesis is the map analysis programme, it was observed that the majority of the learners did not have English as a home language and this may have impacted their scores[1].

The hypothesis that playing the MapTrix Digital Game leads to measurable improvements in map reading scores (using the test-intervention-test evaluation methodology) is supported by the following evidence:

- Showing improved minimum, mean and maximum scores (Figure 8.2), there was an overall improvement of 12.6 % in the map reading scores of the trial population after playing the MapTrix Digital Game. This was recorded after only four learning priods (Table A7.3.1 in Appendix 7.3) during which few learners completed the suggested minimum number of 12 exercises.
- Before the intervention, only 16 % of learners gained ≥ 80 %. After the intervention 45 % gained ≥ 80 %.
- Before the intervention, 31 % gained scores of 50 % or less; this dropped to only 13 % of learners after the intervention.

The brief analysis of the results serves to justify the use of a computer-assisted map reading revision game to prepare learners who are not familiar with computers or who are poor map readers to move to a more advanced, computer-assisted map analysis programme with some degree of confidence. Perhaps more significantly, the MapTrix Digital Game appears to be as effective as *MapTrix* in improving the abilities of learners with below average map skills. The game has the added advantage of improving learners' computer competence by offering an opportunity to interact with novel and relatively complex software.

[1] A second iteration of the prototype has been prepared in English and Afrikaans. If sufficient interest is shown, translation into other languages such as isiXhosa may be possible.

CHAPTER 9

EVALUATION OF MAPTRIX GEOMATICA

'The incomparably beautiful geological map of 1815, ... as vital as it turned out to be for the future of mankind, stands apart – because it was conceived, imagined, begun, undertaken, continued against all odds and completed by just one man ... William Smith'

(Winchester, 2001:3)

9.1. INTRODUCTION

The hypotheses that the self-instruction method can be used to build a learning programme for spatial analysis and that GIS can be used to deliver such a programme were supported by the actualisation of MapTrix Geomatica as discussed in Chapter Seven. In this chapter the efficacy of MapTrix Geomatica is assessed. The test-intervention-test trial procedure is illustrated in Figure 7.3. Differences between the groups that participated in the trials are summarised in Table 8.1 and Figure 7.5 differentiates the trial environments The statistical methods selected for analysing the trial data are described and then the results of the analysis are elaborated. Initially the focus is on the results of the map analysis pre- and post-tests (Appendix 8.4) which are compared with data collected from the participant information sheets (Appendix 8.1) to study the effects of different participant characteristics on their map analysis performance. Then the focus shifts to an evaluation of the component elements of the self-instruction programme and analysis of the data gathered from the exercise sheets (Appendix 8.5) and the opening and closing questionnaires (Appendices 8.2 and 8.6).

Four groups, totalling 63 individuals, participated in the MapTrix Geomatica trials between July and November 2007. The gender of each of the four groups that participated in the trials is illustrated in Figure 9.1 and the overall education levels of the participants in Figure 9.2. The home language of the participants (Figure 9.6) and the age structure (Figure 9.7) are illustrated in the section where the influence of these characteristics on map analysis performance is discussed.

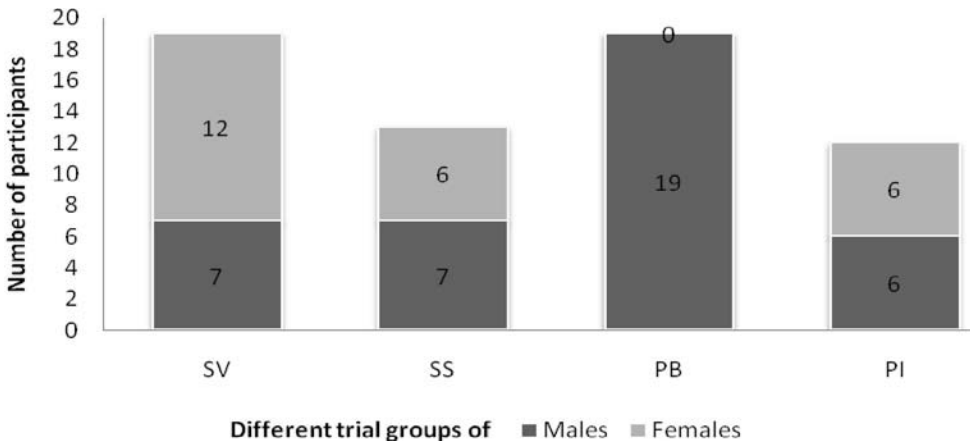


Figure 9.1 Size and gender distribution of the groups that trialled the MapTrix Geomatica prototype (n = 63)

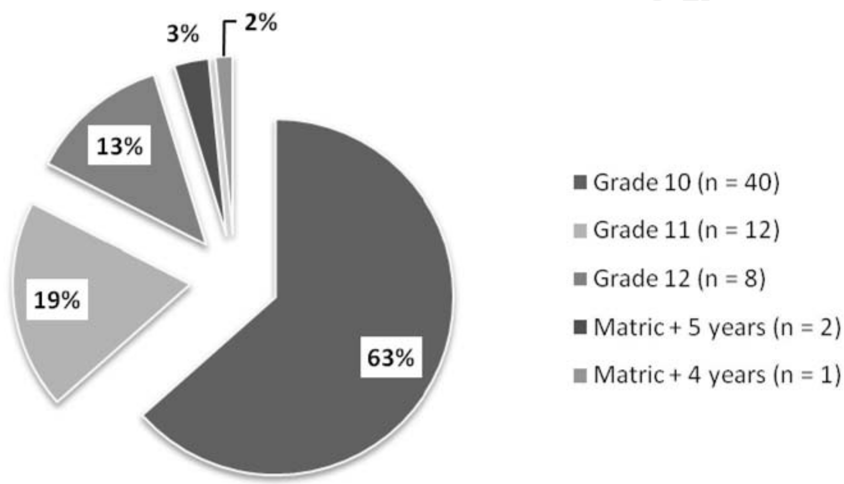


Figure 9.2 Education levels of 63 individuals who trialled MapTrix Geomatica, categorised by Grades (equivalent to years of schooling) and post-Matriculation (school) education

9.2. STATISTICAL ANALYSIS TOOLS AND TEST VALIDATION

From the dataset already described in Chapter Eight (end of 8.1) the quantitative data was extracted for the 63 individuals who participated in the MapTrix Geomatica trials (with their accompanying 184 columns of variables). The Statgraphics Plus computer package (Statistical Graphic Corporation, 1993) was used to conduct the Student's t tests, analysis of variance (ANOVA) and multiple range tests. Excel (Microsoft Office Excel, 2007) was used for calculating certain basic measures and for the linear regression analysis. The latter package was also used to produce all the graphs.

Statistical techniques that were used repeatedly include the following:

- Student's t test was used to find out whether the difference between pairs of datasets was significant (s) or not significant (ns), using the mean, standard deviation (SD) and number of observations (n) in each dataset. The confidence limit or probability (p) was set at 95 % (0.05) in most cases, but was dropped to 90 % (0.1) on occasions as indicated.
- Analysis of variance (ANOVA) was conducted to establish whether mean scores of sub-sets within a dataset differed significantly from each other (also usually at p = 95 % or the 0.05 level). Significant differences between groups were identified using a multiple range test.
- Once sets of ranked data had been plotted as a scatter graph, Spearman's rank correlation (r_s) was used to measure the relationship between them.

As was done for the map reading tests to ensure that there was no bias in the comparison of pre- and post-test results, two banks of questions (the Map Analysis S and T tests in Appendix 8.4) were developed for assessing map analysis performance. Each bank consisted of ten questions totalling thirty marks. The map analysis S and T tests were handed out alternately for the pre-test. Once they had completed the programme, participants received the alternate test as a post-test. The same statistical tests for equivalence were conducted as described in Chapter Eight (and illustrated in Table 8.2). The results are summarised in Table 9.1.

Table 9.1 Comparing score and time to establish the equivalent difficulty of S and T tests when used alternately as map analysis pre- or post-tests

Map analysis evaluation	S Test	T Test	Probability of significant difference
Pre-test - mean score (/30) ± SD	5.05 ± 4.06 (n = 60)	5.75 ± 6.46 (n = 61)	53% ns
Post-test - mean score (/30) ± SD	13.79 ± 7.15 (n = 26)	10.85 ± 6.94 (n = 24)	85% ns
Pre-test - mean time (in minutes) ± SD	18.39 ± 6.01 (n = 60)	19.55 ± 5.25 (n = 61)	74% ns
Post-test - mean time (in minutes) ± SD	23.81 ± 8.16 (n = 26)	22.79 ± 9.00 (n = 24)	32% ns

ns = not significantly different (at p = 95%)

The difference in mean score of 0.7/30 between the S and T tests when used as pre-tests was not significant (p = 95%, n = 121). Unfortunately not all those who wrote the pre-test were able to complete the programme and sit the post-test. However, Student's t test still confirmed that the difference of 2.94 between the mean scores of those who sat the S and T tests as post-tests was not significantly different (p = 95%, n = 50). Time taken to complete the tests was used as a further validation of the equivalence of the two banks of questions in the S and T tests. The small differences in the times taken to complete the S and T tests (1.16 minutes on pre-test and 1.02 minutes on the post-test) were also not significant. The chance of bias in the assessment instrument has thus been eliminated by using two equivalent tests alternately as pre- and post-tests.

9.3 EVALUATING THE EFFECTIVENESS OF MAPTRIX GEOMATICA

9.3.1 Improved map analysis performance

Having ensured that there was no bias in the evaluation instruments, the differences between the participants' pre- and post-test map analysis scores and times could be examined (Table 9.2). Results of the Student's t test show that the map analysis post-test scores were significantly better than the pre-test scores (p = 95%, n = 111) with a mean improvement of 4.02 marks out of 30. The pre- and post-test times were compared to establish whether participants completed the post-test faster than the pre-test to show more efficient performance. The mean difference in time was 1.58 minutes which, according to Student's t test, was not significant (p = 95%, n = 111). Interestingly, rather than taking less time on the analysis post-test, participants took 1.5 minutes longer.

Table 9.2 Comparison of the pre- and post-test scores and times for all participants that trialled the prototype of the MapTrix Geomatica programme

Map Analysis	Pre-test	Post-test	Probability of significant difference
Mean score (/30) ± SD	8.36 ± 6.13 (n = 61)	12.38 ± 7.13 (n = 50)	99.8 % s
Mean time in minutes ± SD	21.74 ± 6.07 (n = 61)	23.32 ± 8.50 (n = 50)	74.4 % ns

s = significant difference (at p = 95%)

The influence of different trial environments (illustrated in Figure 7.5) on trial results had to be identified before investigating the influence of different participant characteristics. When the mean scores for the pre-tests and post-tests were compared (Figure 9.3), no significant difference was found between the four groups (SV, SS, PB and PI) who participated in the trials despite the different conditions under which they trialled the programme. (Group SX, who did not complete the evaluation of MapTrix Geomatica, attained a significantly lower mean score than the other groups on the pre-test (2.44 ± 0.22)[1].

[1] The low scores of group SX for the map analysis pre-test were not unexpected in the light of their poor map reading pre-test scores (already reported in Chapter Eight).

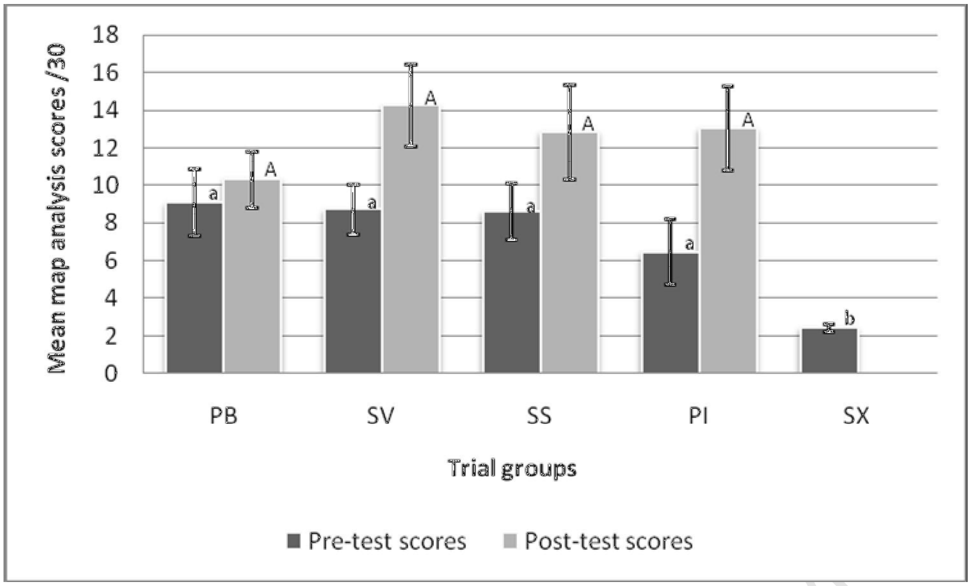


Figure 9.3 Comparison, using ANOVA, between map analysis pre-test scores (p = 95%, n = 122) and map analysis post-test scores (p = 95%, n = 50) of the different groups that trialled MapTrix Geomatica. The vertical lines represent 1 SE. The letters represent the means separation by multiple range tests (lower case for pre-tests and upper case for post-tests)

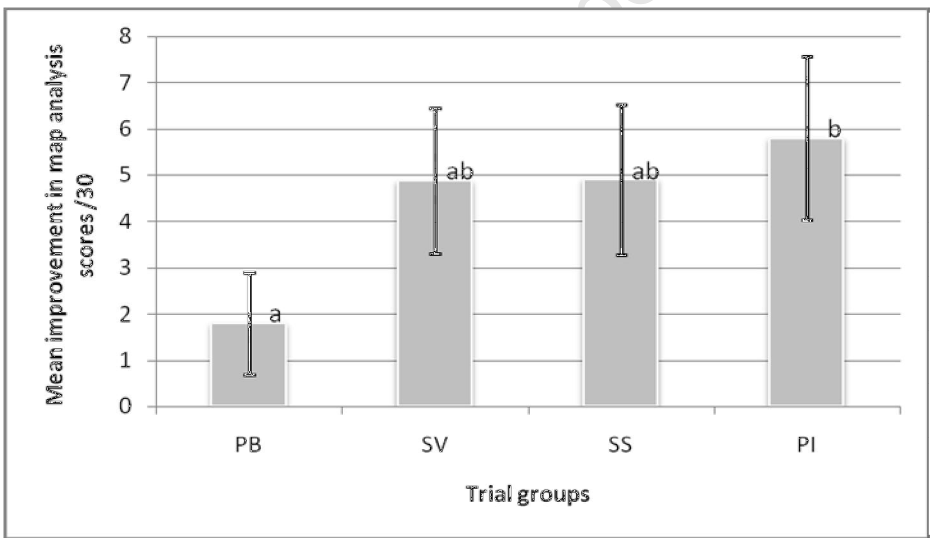


Figure 9.4 Difference between pre- and post-test scores (p = 90%, n = 48) of the different groups that trialled MapTrix Geomatica. The vertical lines represent 1 SD. The letters represent the means separation by multiple range tests

Although a few individual participants did not show improved post-test scores compared to pre-test scores, the mean scores for each group showed an improvement (Figure 9.4). At a probability of 95% the null hypothesis that there were no significant differences between the scores could not be rejected. Three significantly different groups of scores are apparent if the threshold probability is set at 90%. The group that worked fastest and most diligently, Group PI, showed the greatest improvement (5.8 ± 1.76) which was significantly better than the other groups. There was no significant difference between the learners from state schools, Groups SV and SS, who improved by 4.88 (±1.57) and 4.91 (±1.62) respectively. The improvement by Group PB was significantly smaller (1.8 ± 1.11) than the other groups.

9.3.2 Improvements per map analysis task

To evaluate improvements per map analysis task, ten questions in the map analysis tests (Appendix 8.4) were formulated to assess performance on the eight specific skills that had been identified with the help of adult map users (Figure 5.6). Although there are eight lesson topics in the programme (Table 7.1), ten questions were necessary because two tasks each were required to evaluate topic 5 (the identification of contour heights *and* the estimation of height difference) and topic 6 (the measurement of distance *and* the calculation of area). The differences between the pre- and post-test percentages for each map analysis skill indicate that there has been an improvement, albeit variable, in the performance of each task (Figure 9.5).

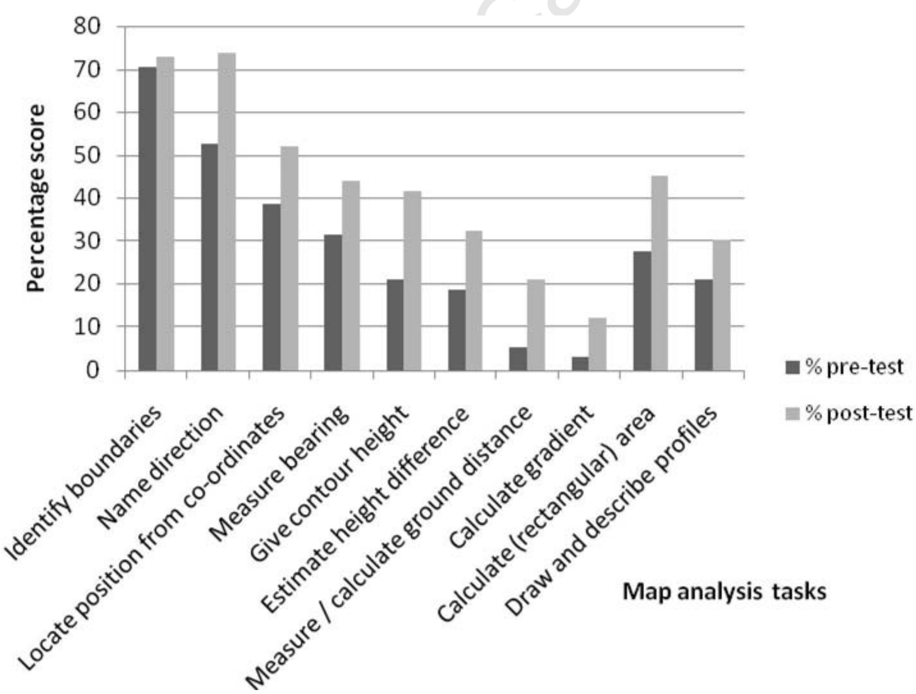


Figure 9.5 Comparison of mean percentages for pre- and post- map analysis tests showing varying degrees of improvement in the different tasks after using the MapTrix Geomatica prototype (n = 48)

Although the calculations of distance and gradient scored the lowest marks in both the pre-test and the post-test, these skills showed the greatest improvement, increasing by 320% and 300% respectively.

The skill with the lowest gain score (3.6%) was the identification of boundaries, probably because there was least room for improvement. Most of the other scores improved by between 35% and 63% while giving contour heights improved by 97%.

9.4 EFFECTS OF INDIVIDUAL CHARACTERISTICS ON MAP ANALYSIS SKILLS

9.4.1 Gender

All five groups sat the map analysis pre-test. There was a significant gender difference apparent in pooled results (p = 95%, n = 123), with males attaining higher scores than females (Table 9.3). Among just the four groups that completed the MapTrix Geomatica trials, males attained higher pre-test scores than females although the difference falls just short of being statistically significant (at p = 95%, n = 61). There was no significant difference between the post-test scores of males and females who completed the map analysis programme, although males had a slightly higher mean score than females. There was also no significant difference between the mean improvement in performance between males and females (p = 95%, n = 50).

Table 9.3 Comparing scores of male and female participants who trialled MapTrix Geomatica

Map Analysis	Male mean (/30) ± SD	Female mean (/30) ± SD	Probability of significant difference
Pre-test scores (all participants – 5 groups)	6.42 ± 0.75 (n = 67)	4.18 ± 0.53 (n = 56)	97.89 % s
Pre-test scores of 4 trial groups who completed the programme	9.55 ± 1.09 (n = 37)	6.52 ± 1 (n = 24)	94.15 % ns
Post-test scores of 4 trial groups who completed the programme	13.29 ± 1.24 (n = 34)	10.44 ± 1.7 (n = 16)	81.05 % ns
Mean improvement (difference between pre- and post-test scores)	4.14 ± 0.89 (n = 34)	3.72 ± 1.41 (n = 16)	20.31 % ns

9.4.2 Home language

South Africa has 11 official languages, only three of which were spoken by the trial participants. The majority spoke English at home and a small group spoke different European languages (French, German and Russian) which have been grouped as non South African languages. Because the language of the self-instruction programme is English, it was anticipated that home language would have an impact on the performance of the participants (see Figure 9.6).

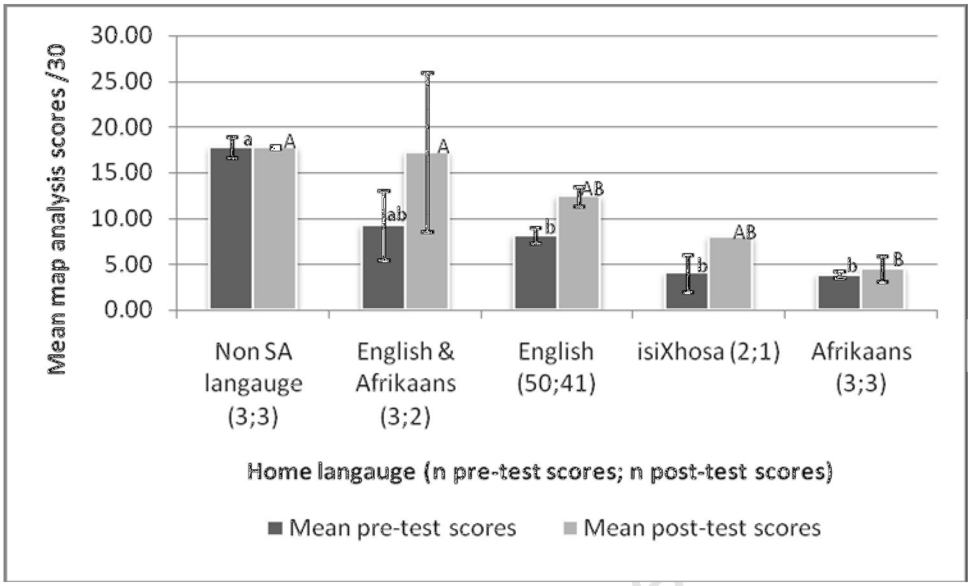


Figure 9.6 Effects of home language on pre- and post-intervention map analysis test scores using ANOVA (p = 95%, n = 61 on pre-tests and n = 50 on post-tests). The vertical lines represent 1 SE. The letters represent the means separation by multiple range tests (lower case for pre-tests and upper case for post-tests)

In the pre-test, the non-SA language speakers attained the highest mean score which was significantly different to the rest of the participants. The score of the bilingual (English and Afrikaans) speakers was not significantly different from any of the other groups. There was no significant difference between the mean scores of the majority, who spoke only English at home and the two, who spoke isiXhosa, nor the three Afrikaans home language speakers. The scores were all disappointingly low considering that map skills are a requirement of the Social Sciences learning area in the Revised National Curriculum Statement (RNCS) for the GET phase (DoE, 2002a). The majority of these learners, being in Grade 10 (see Figure 9.2), would have completed this phase at the end of Grade 9 the previous year.

On the post-test all participants, except the non-SA language speakers, showed improved mean scores. The participants who had the most improved scores were those who spoke English and Afrikaans giving them results not significantly different from the non SA language group. The improved post-test mean score of those who spoke English at home, was not significantly different from the single isiXhosa speaker. The mean post-test score of the Afrikaans speakers was significantly lower than the two most improved groups.

9.4.3 Age

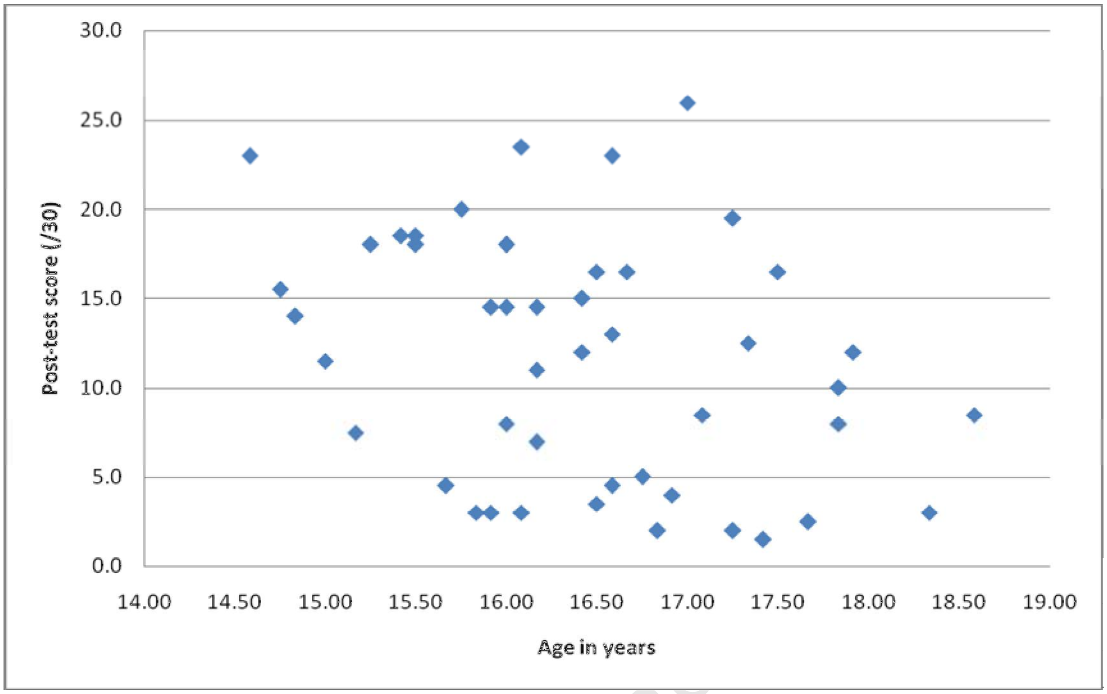


Figure 9.7 Relationship between age and map analysis post-test scores of school-based participants in the MapTrix Geomatica trials

The three adult participants who make up only 5% of the sample (see Figure 9.2) were excluded from this evaluation on the grounds that they might skew the results. The ages of the sample population range from 14.48 to 18.75 years. A reasonable level of map analysis ability and an improvement with age was expected. However, Figure 9.7 illustrates a very weak negative correlation (r_s = -0.33) between age and map use proficiency as indicated by the map analysis post-test scores. This suggests that map users in the sample population do not demonstrate improvement with age, indeed, older participants performed less well.

9.4.4 Access to and attitude towards computers

It was assumed that access to computers would influence the participants' ability to perform well on a computer-assisted learning programme. From the opening questionnaire (Appendix 8.2) the responses to the question: *If you use a computer, where do you use it*? were categorised and coded to represent five options including combinations of *school*, *home* and *elsewhere*.

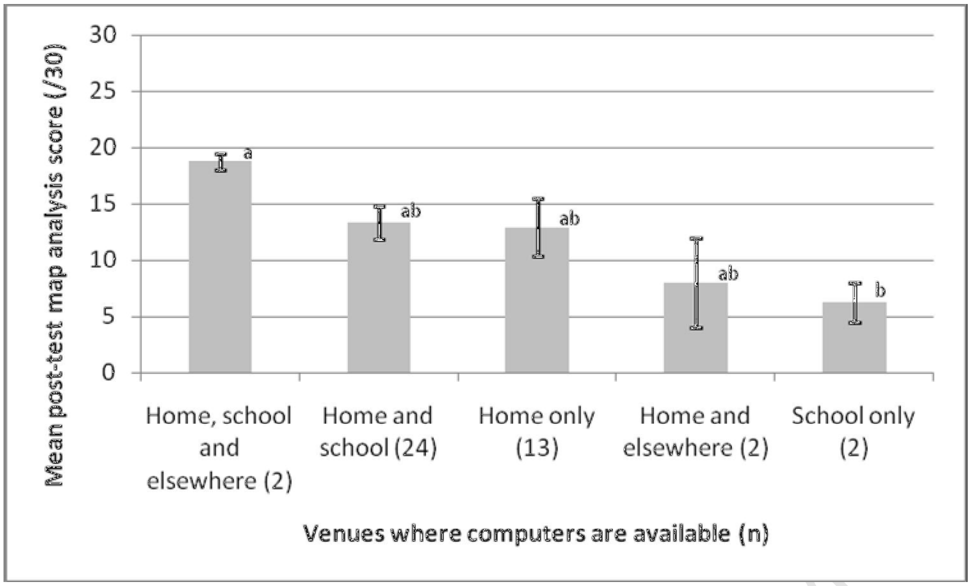


Figure 9.8 Impact of access to computers on map analysis post-test scores assessed using ANOVA (p = 90%, n = 43). The vertical lines represent 1 SD. The letters represent the means separation by a multiple range test

Figure 9.8 illustrates that a total of 43 participants completed the opening questionnaire and the map analysis programme (including pre- and post-tests) of which 41 have access to a computer at home. Although there was no significant difference between the groups at the 95% confidence level, at the 90% level, a difference emerges between those who use computers at home, school and elsewhere compared with those who have access to computers only at school. There was no significant difference between the other groups, although the largest group, who have access to computers at home and at school, attained the second highest mean score. It was also assumed that those who had selected Information Technology or Computer Applications Technology as FET electives would have an advantage over the others because they would have more access to computers. When applying ANOVA to the map analysis post-test scores, surprisingly, no significant difference between the group scores at a probability of 95% is apparent. The 22/43 who had selected an IT option at school had a mean score of 12.95 ± 1.56 while the other 21/43 had a score of 12.76 ± 1.61.

To find out whether MapTrix Geomatica had changed participants' attitudes to using computers, they were posed the same question on both the opening and closing questionnaires. They were asked to tick one of five words, rated 1 to 5, describing their feelings (see Figure 9.9). There was a general shift up the scale from *scared* to *confident*. Before the intervention only 35.19% of the participants indicated that they felt confident when using computers. This increased to 62.79% afterwards. This positive trend is noted despite the relatively complex nature of the programme which required learners to switch between the PowerPoint and GIS programmes and to execute various tasks using GIS tools.

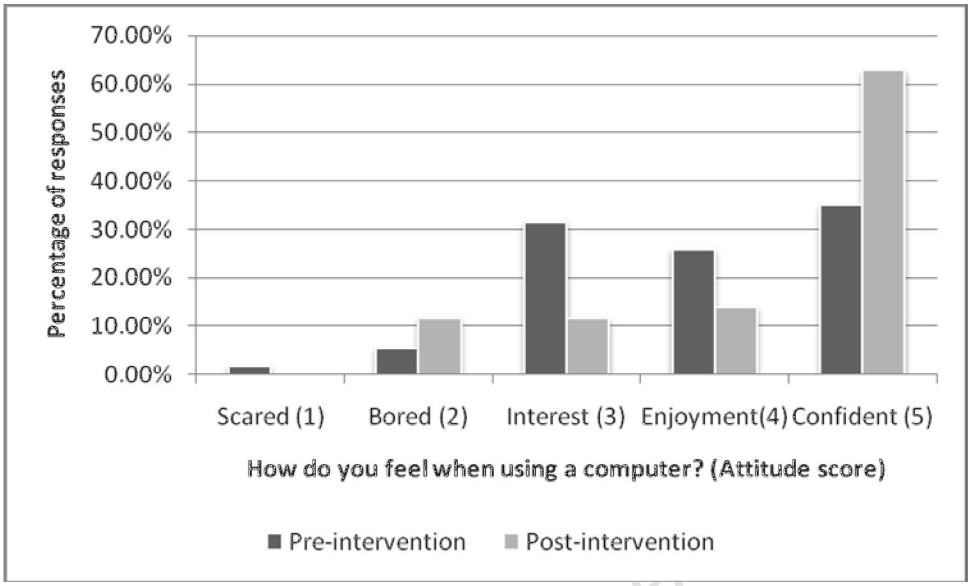


Figure 9.9 Assessing participants' attitudes to using computers before (n = 54) and after (n = 43) the MapTrix Geomatica trial

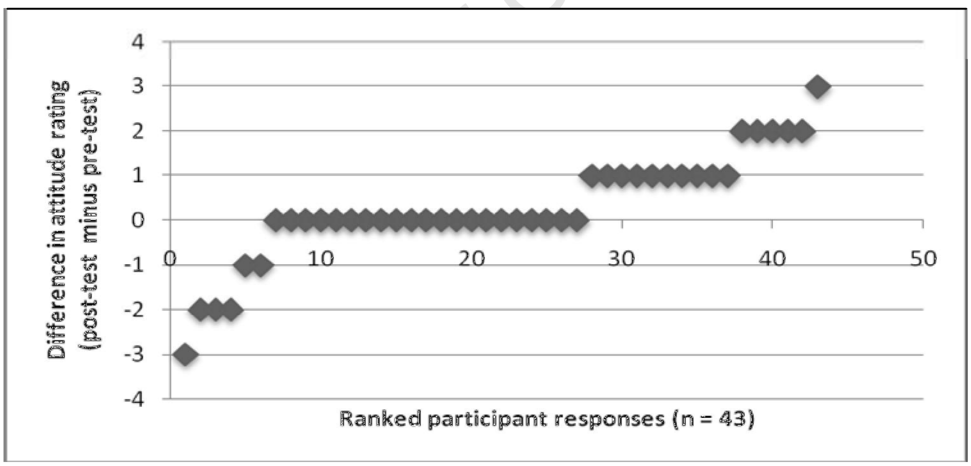


Figure 9.10 Change in participants' attitudes towards using computers after the MapTrix Geomatica trial

Reasons for the negative shift in categories *bored*, *interested* and *enjoyment* were identified by comparing individual pre- and post intervention attitude scores (Figure 9.10). The six participants who showed a negative trend were learners in Groups PB and PI for whom computer assisted learning was no novelty (hence a few were *bored*). Group PB's negative attitude towards GIS, which was revealed in discussion with their teacher (Appendix 7.4), impacted the *interest* and *enjoyment* scores. The majority of participants (21) showed no change in attitude to computers, while 16 indicated a shift towards greater *interest*, *enjoyment* or *confidence*.

9.4.5 School subject combinations

Information gathered in the participant information sheet included subjects selected for the school leaving certificate. The combination of Geography with Mathematics and Science is of particular interest. No matter what their subject combination, the mean scores of all groups improved but the analysis of variance showed that even at 95% probability, there was no significant difference between these improvements. Analysis of variance on post-test map analysis scores reveals more marked differences between subject combination groups.

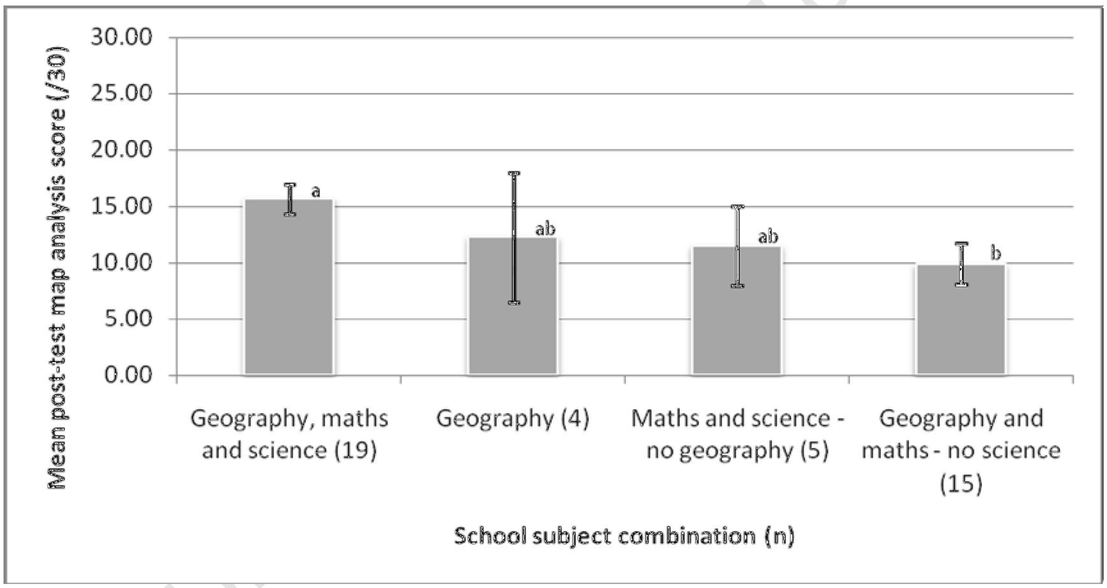


Figure 9.11 Effects of school subject combinations on post-test map analysis scores. Vertical lines represent 1 SD. Letters represent means separation by a multiple range test (p = 95%, n = 43)

Figure 9.11 illustrates that those who had selected Geography, Mathematics and Science performed best on the map analysis post-test and their mean score was significantly better than the other groups. Surprisingly, there was no significant difference between the mean scores of the Geography only group and the group who were not continuing with Geography but were taking Mathematics and Science. The second largest group appear to gain no advantage in taking Mathematics with Geography as their scores were significantly lower than other groups.

9.4.6 Attitude to maps

To assess the effect of attitude to maps on map analysis competence a series of questions was asked about maps in the opening questionnaire (Appendix 8.2). Depending on the participants' responses, the answers were scored to provide a measurable value for their attitude to maps (see Table A8.8.1(a) in Appendix 8.8). Figure 9.12 illustrates a weak positive correlation (r_s = 0.39) between attitude ratings and post-test scores. Very few individuals scored on the negative side of 10 (neutral), the majority had a positive to very positive attitude to maps. Generally those learners with the most positive attitude attained the highest scores and those with the poorest attitude to maps had low test scores. However, a large number who indicated that they liked maps still scored badly on the map analysis post-test. As might be expected, the results suggest that learners do well at what they enjoy. They also suggest that there is potential for skill improvement if learners with a positive attitude to maps are afforded more opportunity to practise map skills.

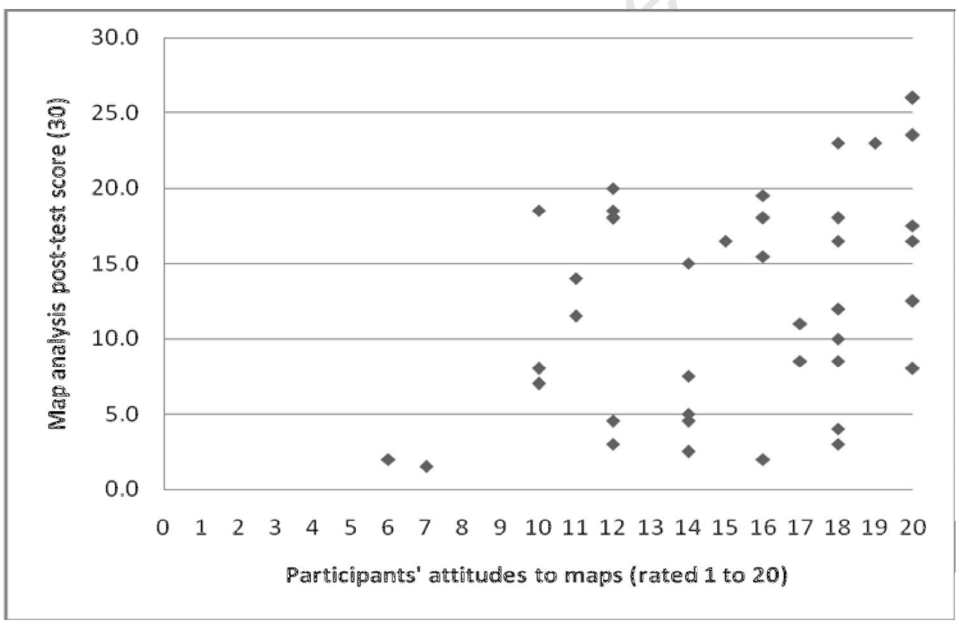


Figure 9.12 Relationship between participants' attitude to maps and their map analysis post-test scores. Attitude rating: 0 = maximum negative score, 10 = neutral, 20 = maximum positive score

9.5 EVIDENCE OF INTERACTIVE LEARNING - MAP ANALYSIS EXERCISES

The exercises are a pivotal component of the learning programme (Figure 10.1) because they draw attention to the terminology and concepts that participants must understand and they provide the opportunity for them to demonstrate the competence gained in an interactive, self-instructed, learning situation. Each exercise comprises ten questions worth one mark each. Model answers are provided for participants to assess their own responses. Self-assessment was done by all groups for all exercises, except in the case of Group PB who only self-assessed the exercises on the first two lessons (reasons discussed in Appendix 7.4).

9.5.1 Checking participants' answers to the exercises

There were 16 exercises, two for each map analysis lesson, the second exercise providing a repeat opportunity to practice and consolidate skills. Participants were advised to complete one of the exercises following a lesson and to mark their answers. If their scores were less than 8/10, they should attempt the other exercise to improve their scores for the relevant skill before going on to the next lesson. After the first lesson, the exercises on each subsequent lesson include questions that require the skill(s) learned in the previous lesson(s) for reinforcement.

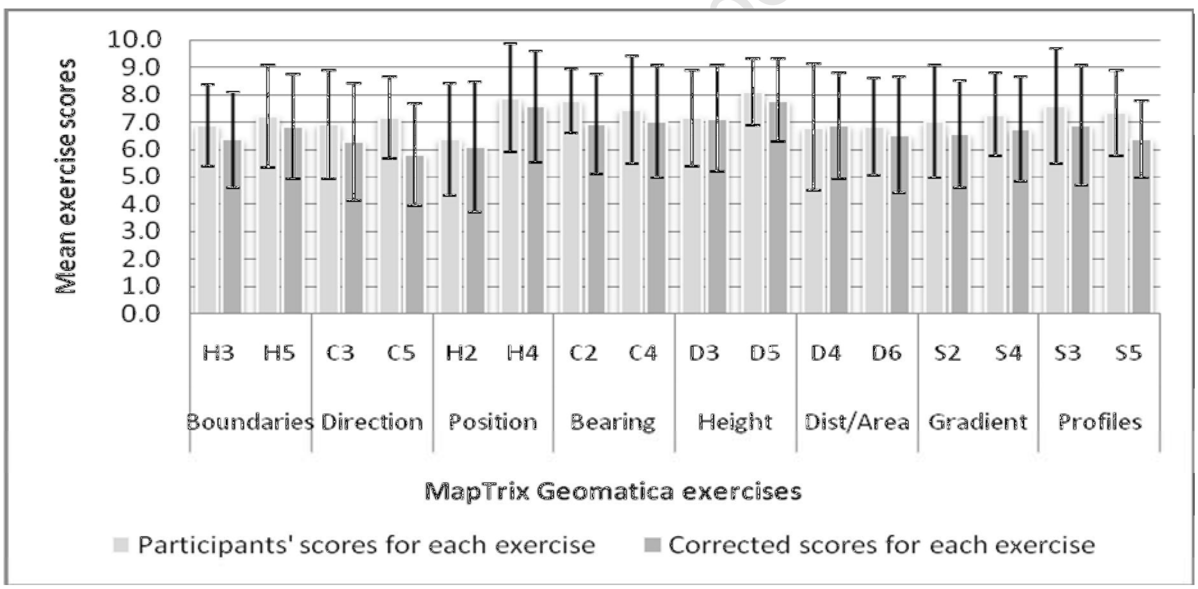


Figure 9.14 Comparison between participant inflated scores and corrected scores per exercise (H = Hearts, C = Clubs, D = Diamonds and S = Spades) (n = 12 to 39)

Once all the exercise data had been entered and analysed, the consistently high scores for the exercises on all the lessons in the programme compared with the declining scores for questions in the post-test raised the suspicion that the exercise scores may have been inflated. This was confirmed by conducting spot checks on the accuracy of learners' self-assessment. All the exercises on each of the eight lessons were then reassessed by the researcher and the new data added to the dataset. A consistent self-assessed over-allocation of marks is apparent in Figure 9.14. Student's t test was used to compare participants' mean scores per exercise with the corrected scores. When the mean exercise scores were pooled, there was a significant difference (at 95 % probability, n = 332) between the participant scores and the checked scores.

However, when each exercise was evaluated individually, only exercise C5 on direction showed a significant difference between the participant assessed and the researcher assessed scores. For the ten questions in exercise C5, four required two-part answers whereas most other exercises required none or only one or two multiple answers. Participants had tended to award full marks for each half of a correct answer thereby inflating the total exercise score. While reassessing the answers it was found that most differences that arose related to multiple answers. Some participants awarded themselves a full mark when only a half-mark was appropriate for inaccurate answers (outside the 10 % tolerance allowed) or for answers without units of measurement. Occasionally participants made addition errors and sometimes rounded total exercise scores up to the next whole number.

Participants had all been reminded that part of their function in participating in the trials was to identify errors in the programme. Very few brought errors to the attention of the researcher and those that did identified mainly textual errors in the lessons. Incorrect model answers were a further cause of mismatches. This happened because the editions of the two maps that had been used to set the direction exercises for lesson two were more recent than the editions that had been imported into the GIS (reported in Appendix 9.1). This oversight was only pointed out to the researcher once the trials were well underway. The model answers were adapted so that participants' exercise scores were not negatively impacted.

Participants answered the exercise questions on the first two lessons (boundaries and direction) using the GIS software to view the relevant maps on screen. From the third lesson onwards participants were instructed, and then repeatedly reminded, that all answers requiring measurements should be worked out manually using the mathematical equipment and hard copy maps provided on the *MapTrix* work cards. They should only use the GIS tools to check their calculations. The answers worked out on the paper copy maps were taken by the researcher as correct. Some learners had disregarded this instruction and had awarded themselves marks based on their GIS generated answers, which they had assumed to be more accurate than the answers supplied. They did not realise that the correct fixing of end points, using the GIS measurement tool on screen, has a dramatic influence on the accuracy of GIS measurements and that the GIS answers they were generating were not in fact correct.

After the reassessment of the answers, a potential error analysis on each exercise was conducted (Appendix 9.2) to evaluate whether the ten questions in each of the sixteen exercises were of equal difficulty. The number of times each exercise was attempted averaged 26, ranging from 37 to 39 for the first three skills to less than 20 attempts for the last four skills (reflecting the declining number of participants that completed the programme). On average, 32 % of the answers supplied per exercise were incorrect (or had been omitted). The potential error analysis revealed noticeable differences in the difficulty level of the two exercises set for some lessons. For example, there is a 15 % difference between the mean scores for exercise H2 and H4 on the position lesson and a 7 % difference between exercise D3 and D5 on height.

9.5.2 Exercise scores per lesson and per trial group

Once the exercise scores of participants had been checked, the corrected scores were used for all further analysis. After the trials, the average of the two exercise scores per lesson was calculated.

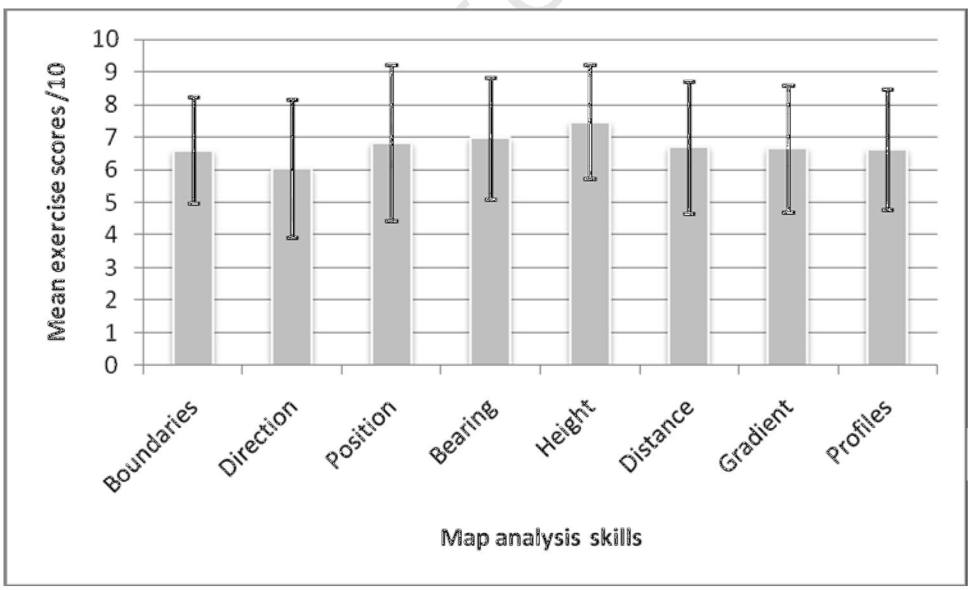


Figure 9.15 Mean scores for both exercises based on each map analysis lesson in the MapTrix Geomatica prototype. Error bars represent one standard deviation (n = 16)

As Figure 9.15 illustrates, the mean exercise scores for all participants ranged between 60 % (for direction) and 75 % (for height).While the mean exercise scores did not reach the 80 % mastery level which was set as a benchmark (as discussed in Chapter Eight with reference to Table 8.3), the mean score for all skills was between 60 % - 69 % which is regarded in the Subject Assessment Guidelines

(DoE, 2008) as indicating *substantial achievement*. There were no significant differences (at p = 95 %) between mean exercise scores per lesson and little evidence of the decreasing scores per skill found in the map analysis pre- and post-tests (Figure 9.5).

To examine the trends in the mean scores per skill for each group, they have been plotted in Figure 9.16. Group SS produced the best scores for most skills, generally maintaining their score levels despite the increased difficulty of the skills. Group SV, who were the only group not restricted by time, had lower starting scores but these tended to increase towards the end of the programme. Group PB had the most erratic and probably the most unreliable scores. Only three got as far as the exercises on gradient. None of the boys completed the lesson and exercises on profiles and very few attempted more than one exercise per lesson. Unfortunately, members of this group showed the greatest tendency to cheat (Appendix 7.4). Only Group PI, whose scores were consistently the lowest, attained scores below 50 % and these were for the last two skills in the hierarchy; gradient (49 %) and profiles (46 %). While most completed the programme in the two days that were available, there was not enough time for members of this group to attempt an additional exercise on each lesson.

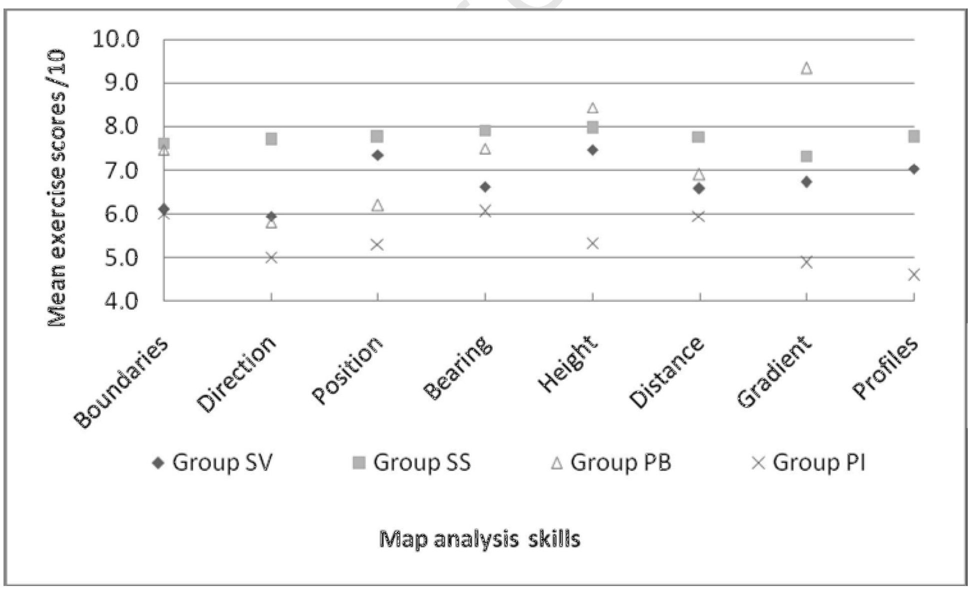


Figure 9.16 Map analysis mean exercise scores for the different groups that trialled MapTrix Geomatica

Apart from the variations between the trial groups, general mean exercise scores were maintained at a relatively high level despite the increased difficulty and complexity of the skills being assessed (see Figure 9.17). While every attempt will be made to clarify the questions in the exercises when developing the programme further, scores of over 60 % confirm the suitability of the order of the lessons and of the structure of each exercise which includes questions that help to reinforce the incremental accumulation of the selected map analysis skills.

9.5.3 Comparing pre- and post-test scores with map analysis exercises

The scores for the ten questions in the map analysis pre- and post-tests were matched with the eight map analysis skills in the learning programme by combining test questions 5 and 6 on height (lesson 5) and test questions 7 and 9 on distance and area (lesson 6) (adaptation illustrated in Appendix 9.3). This made it possible to compare pre- and post-test scores (Figure 9.5) with group exercise scores for each map analysis task in Figure 9.17. Ideally, if the programme is effective, all the graphs should follow the pattern of group SV's scores for direction: low pre-test score, mean score for two exercises higher but not necessarily significantly different to the pre-test, post-test score higher than exercise score and significantly better than pre-test score.

In Figure 9.3 the significant differences (at p = 95 %) between the mean pre- and post test scores per group were illustrated. When the group scores are broken down and plotted per skill (Figure 9.17) the difference between pre- and post-test scores shows significant improvement (at p = 90 %) in seven of the eight skills (not height) but for only one of the four groups in each case. Significant differences are revealed between the exercise scores and the pre- and/or post-test scores for all tasks: boundaries (1 of 4 groups), direction (1 of 4 groups), position (3 of 4 groups), bearing (3 of 4 groups), height (4 of 4 groups), distance (4 of 4 groups), gradient (4 of 4 groups) and profiles (3 of 3 groups that completed exercises). In the majority of cases, the exercise scores are higher than the test scores. This difference becomes more marked when moving up the skills hierarchy because the pre- and post-test scores become progressively lower. To ensure that learners using the programme in future gain maximum benefit from the programme, reasons for the high exercise scores compared with low test scores were examined.

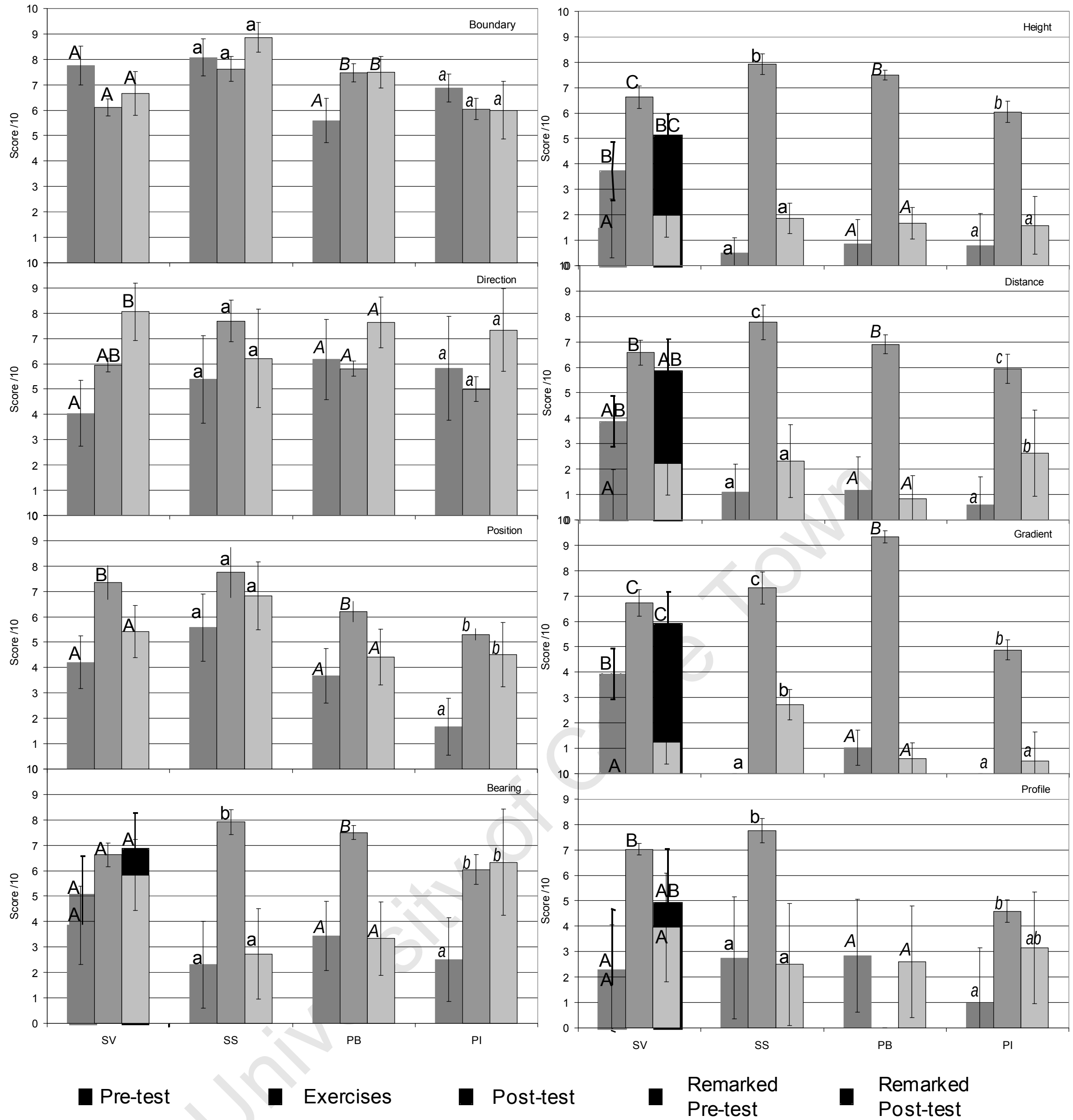


Figure 9.17 Comparison, using ANOVA, between map analysis pre- and post test scores (p = 90 %, n = 48) and between them and the mean exercise scores for eight map analysis lessons (p = 90 %, n = 16). The vertical lines represent 1 SE. The letters represent the means separation by multiple range tests (upper case for Group SV, lower case for Group SS, upper case italic for Group PB and lower case italic for Group PI). Cross-hatching represents the difference between accurate and flexible assessment of pre- and post-test answers for Group SV

The most noticeable feature of Figure 9.17 is the difference between the first four skills which generally have higher scores for exercises and tests and the last four skills which generally have high scores for the exercises but much lower scores for the tests. The difference between the scores for tasks requiring word and number answers is clear. The answers to the questions on boundaries, direction and position (the first three analysis skills) were verbal (word) answers and the differences under discussion are less marked. From bearing to gradient, all the answers were numeric (numbers) and the difference between exercise and the pre- and post-test scores becomes increasingly obvious. The scores for profiles are not as low as might be expected from the declining test score trend, perhaps because the answers required a sketch and selecting a statement to match the shape of the profile, again a verbal not numeric answer.

Numeric accuracy was also investigated. In order to ensure consistency in the assessment of all tests, very rigid marking memoranda were developed for the map analysis S and T tests. Very little leeway had been allowed in the values of numeric answers and only answers with the relevant unit of measurement were awarded full marks. No marks were awarded for map distances in centimetres that had not been converted to ground distance. The questions on the first three lessons (boundaries to position) had only one possible correct answer and were not reassessed. The more flexible marking scheme for questions on lessons four to ten (bearing to profiles), is detailed in Appendix 9.4. In the adjusted memorandum, half marks were given for correct centimetre distances with or without the correct unit of measurement; a partial mark was awarded for stating the correct method.

The net effect of less stringent marking on the scores of Group SV, shown by the hashed bars in Figure 9.17, were increases in the pre-test mean score from 29 % to 38 % and post-test mean score from 48 % to 58 %. The difference between scores before and after the intervention (comparing the cross-hatched and solid fill bars) improved from 19 % to 20 %. As illustrated in Figure 9.17, these improvements were significant (but only at p = 90 %) for height, gradient and profiles. It is not suggested that the original marking was too stringent but rather that there was insufficient guidance offered in the programme to participants on how to ensure the accuracy of their answers and on how to self-assess accurately.

9.5.5 Participants' assumptions of 'easiness' compared to pre- and post-test scores

In the opening questionnaire (Appendix 8.2), participants were given a list of the eight map analysis skills and asked to indicate those with which they had experienced difficulties prior to the trials. Skills not ticked were assumed to be easy by default. The percentage of participants that found each task easy was calculated and plotted in Figure 9.18. To check whether they had indeed performed better on the tasks that they had identified as not difficult, the mean pre-test scores were also plotted for each skill.

As Figure 9.18 illustrates, the majority of participants over-estimated the easiness of all the map analysis tasks except boundary identification. The skill of boundary identification was included in the programme specifically because of the significance of bounded space when using GIS but few geography textbooks in use to teach map skills at the time of the trials addressed the issue of boundaries. Due to the lack of familiarity with the topic, participants assumed that boundaries would be difficult whereas their scores indicate that it was the easiest task. The greatest discrepancy between presumed ability and score is with the skill of accurately measuring and calculating distance and area. One reason may be that it is a common practice to teach a shortcut method of converting map distance to ground distance i.e. ground distance = map distance ÷ 2, although this only works when map scale is 1:50 000, map distance is measured in centimetres and ground distance must be expressed in kilometres. Ground distance in metres was required for the answer to question seven in the pre-test for which a mean score of only 5 % was attained (Appendix 9.3).

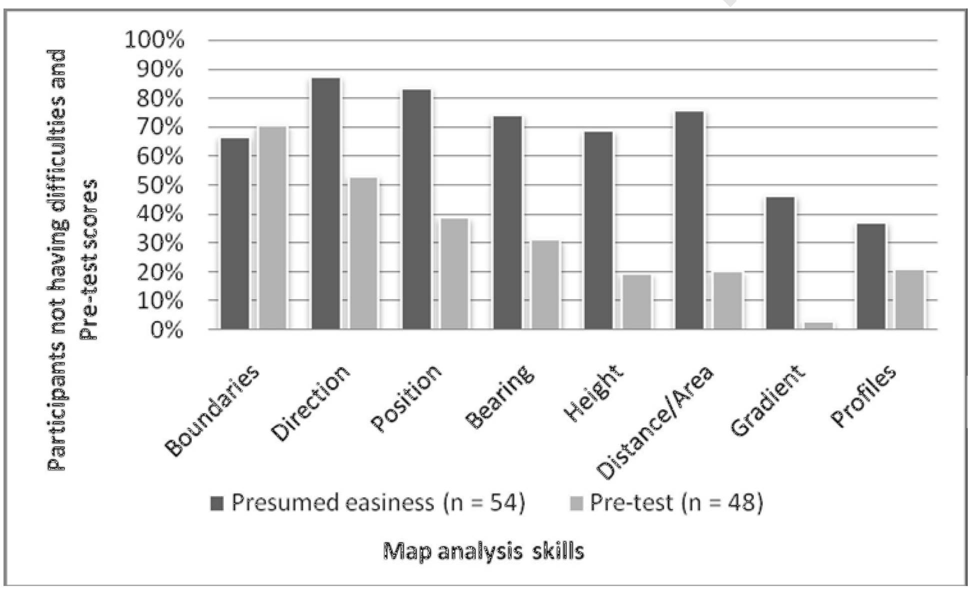


Figure 9.18 Pre-intervention assessment of the easiness of map analysis skills. Double Y axis used to plot both percentage of participants who did not have difficulties with skills before the intervention and pre-test scores per skill (see also Figure 9.5)

The pre-test scores for each skill decline steadily with the increased difficulty of the tasks to skill seven, the calculation of gradient. Although the majority of participants assumed that profiles would be the most difficult, their pre-test scores for this skill were better than for some of the tasks considered less difficult. This is probably because the common method of assessing profiles does not always provide participants with a previously prepared framework for drawing a profile in which the base line accurately represents the map distance and which already has appropriate heights indicated on the vertical axis (as was provided in pre-test question ten, Appendix 8.4). This guidance made the completion of the profile sketch relatively easy. The second part of the question required participants to match a verbal description of the landscape with the shape of the completed profile. This was also a relatively easy task because heights were indicated on the profile frame. These factors may explain the higher mean pre-test score for profiles compared to the anticipated difficulty.

In the closing questionnaire, participants were asked whether the programme had helped them improve the skills with which they had experienced difficulties before the trials. The response of 87 % was *yes*, 4 % were undecided and 9 % indicated that they felt the intervention had not helped. When reviewing the reasons given for the negative responses, the majority were from Group PB who had not completed the programme and therefore had not reached the lessons that they had identified initially as being problematic.

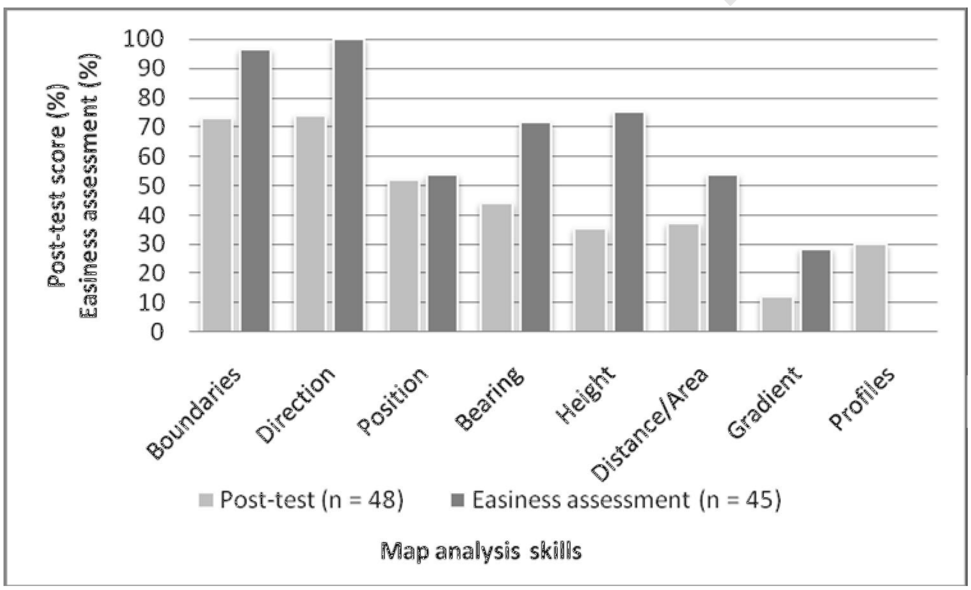


Figure 9.19 Post-test scores compared with post-intervention assessment of the easiness of the lessons on the eight map analysis skills in the MapTrix Geomatica prototype

Also in the closing questionnaire participants were given the opportunity to indicate which lesson they found the hardest to learn and which the easiest. From their responses a presumed easiness rating was derived by subtracting the number of times each lesson received a hardest lesson vote from an easiest lesson vote. To derive positive values, the maximum negative value was added to each score. These were summed and the easiness rating per lesson was expressed as a percentage. When assessing how easy or difficult participants had found the lessons, not one participant had rated profiles as easy yet the post-test score for this topic was not the lowest (Figure 9.19). Gradient was rated easier than profiles yet the score was lowest. Amongst the other six skills, the only one where the post-test score and easiness rating almost coincide is position. Of the remaining skills, participants assessed the lessons as easier than their post-test scores reflected.

The findings here underscore that learners appear to be over-confident of their ability to perform the tasks which have a mathematical focus and numeric answers (such as bearing, height, distance/area and gradient). They assessed these as relatively easy yet attained poor scores in the post-test (Figure 9.19). It would appear that, while the concepts presented in these lessons were understood and participants answered the questions in the exercises with relative ease, problems arose in reaching the required levels of accuracy when answering the post-test questions.

9.6 THE GIS COMPONENT OF THE MAPTRIX GEOMATICA PROTOTYPE

The reason for using the computer learning environment for the advanced version of *MapTrix* was, *inter alia*, the inclusion of GIS in the new curriculum for Geography (as discussed in Chapter Seven - 7.1.2). Microsoft PowerPoint™ was used to present the lessons, exercises and answers, TNTMips GIS software was used to deliver the maps on which the exercises were based and to provide the interactive links between maps and lessons. Staff of Naperian GIS Technologies made a major contribution towards the compilation of both software components. As illustrated later (Figure 9.24) participants rated the GIS components (both sub-lessons and practical activities) as the most useful parts of the map analysis skills lessons. However, GIS was much more than just part of the lessons, the GIS software was used as both a learning material delivery mechanism and a learning tool, integral to the functioning of the MapTrix Geomatica programme.

Because the GIS components of the programme were of special interest, participants were asked a number of questions about GIS, starting with whether they had used all the GIS sub-lessons that formed part of some map analysis skills lessons (Table 7.1). An introductory lesson on GIS was delivered at the start of the trials (based on the outline in Appendix 7.6), the link to the GIS sub-lesson appeared on the front page of each lesson (Figure 7.2) and at points within relevant lessons. The majority (74 %) of participants used the sub-lessons but 26 % did not. Figure 9.20 indicates the ways in which those who used the GIS sub-lessons found them useful. Of those who gave a negative response, 17 % indicated that they did not need *all* the sub-lessons suggesting that some had been used. Most of those who cited technical difficulties (9 %) were in Group PB. Their problems were caused mainly by the incorrect installation of the programme and this was resolved during the trials (Appendix 7.4).

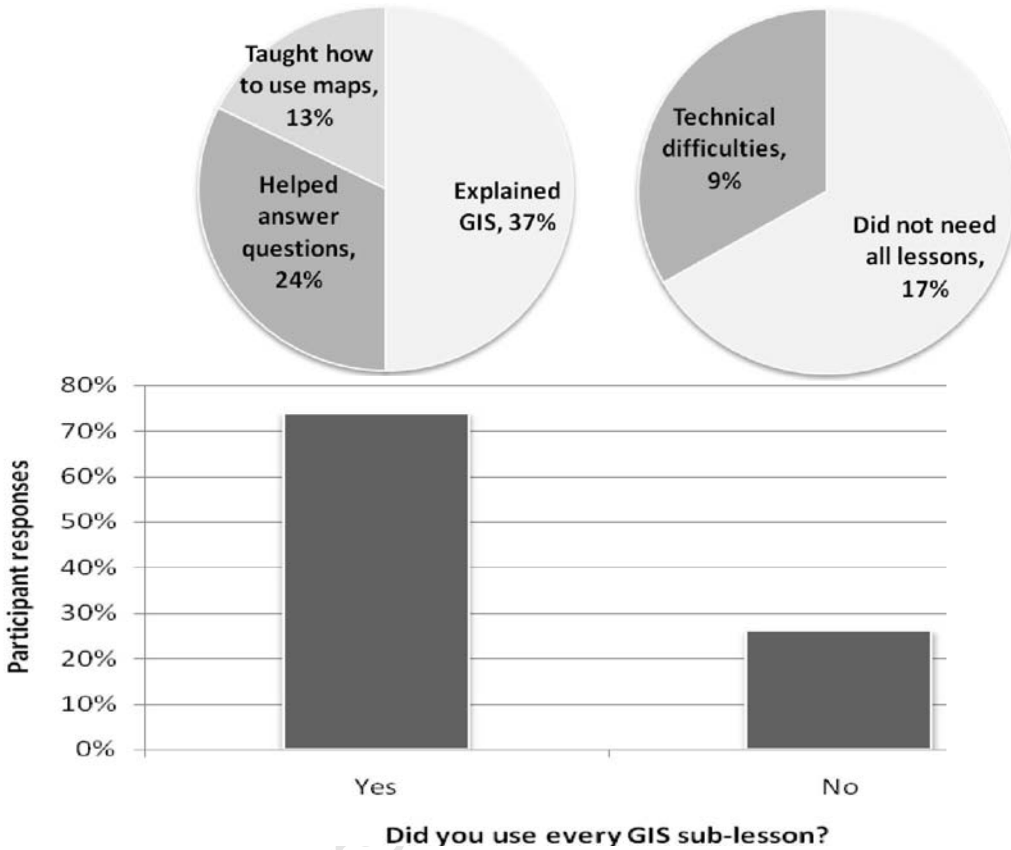


Figure 9.20 Percentage of participants (n = 46) who opted to use or not use the GIS sub-lessons in the MapTrix Geomatica prototype (represented by bar graphs) and their reasons for doing so (corresponding pie graphs)

When asked what advantages GIS has over paper maps, a large range of enthusiastic free responses were received. Less than 5 % of responses indicated that GIS had no advantages over paper maps. The advantages were categorised as illustrated in Figure 9.21. It is clear that the main advantage was the zoom function (33 % of responses) with the second most often mentioned advantage being that GIS made maps (spatial information) easier to understand (26 %). This may also be related to the zoom function which makes features easier to see when they are enlarged.

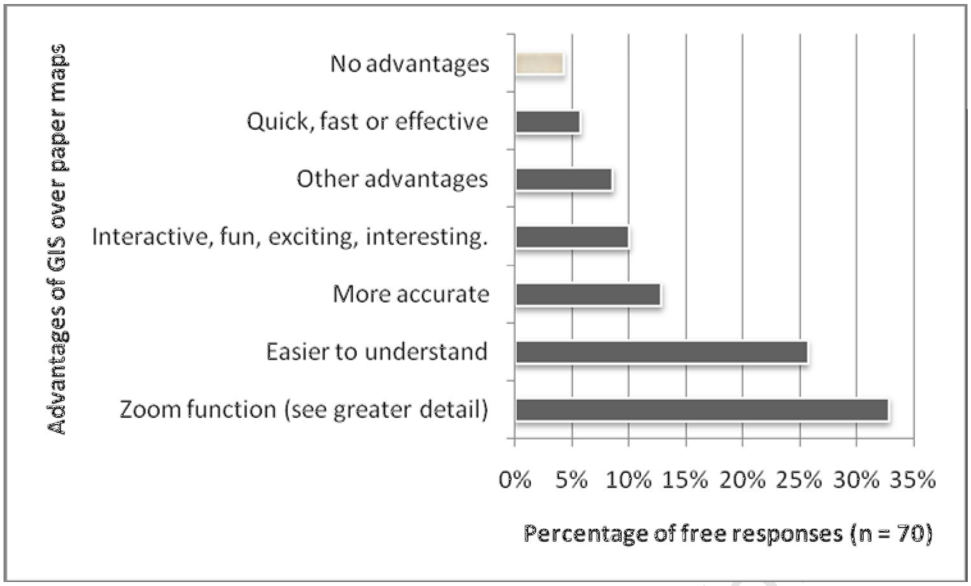


Figure 9.21 Advantages of GIS over paper maps as identified by participants in the MapTrix Geomatica trial (most participants gave more than one response)

These enthusiastic responses were reflected in other answers in the closing questionnaire as well. To assess whether the participants' interest in GIS had been stimulated by their exposure to the software in the MapTrix Geomatica programme, their answers to the question: *Would you like to know more about GIS?* are categorised as *Yes, Undecided* and *No* (Figure 9.22). While 75 % of the participants wanted to know more about GIS, there are interesting differences between the four trial groups.

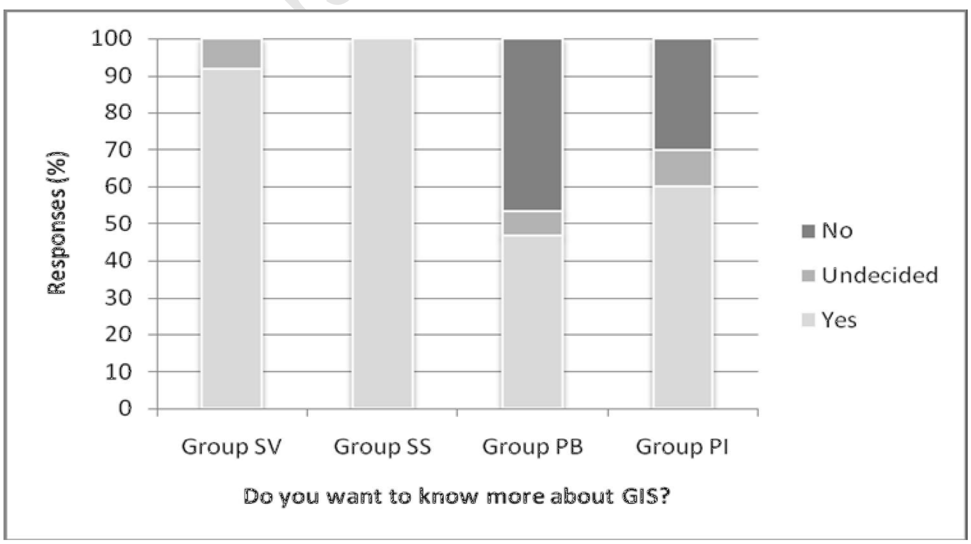


Figure 9.22 Participant desire to know more about GIS after completing the MapTrix Geomatica trials. (Group SV, n = 12; Group SS, n = 11; Group PB, n = 15; Group PI, n = 10)

The all boys group (PB) was the only group that had prior experience of GIS; they returned more *no* responses than any of the other groups. Group PI included the highest percentage of non-Geography learners which may account for their *no* responses. Both groups from state schools (SV and SS) were very keen to know more about GIS, many possibly enjoying the novelty of learning with computers as much as the software itself. When participants were asked whether they thought that learning map analysis skills was better with GIS than without (and to give reasons for their answers) 63 % indicated that they preferred to use GIS and a further 17 % suggested using both paper maps and GIS bringing the total in favour of using GIS to 80 %. Reasons given for using (or not using) GIS are illustrated in Figure 9.23. Four participants correctly noted that there are no computer facilities in examination rooms for Geography (as yet) and gave this as a reason for not using GIS to learn map analysis skills. Preference for paper maps was indicated by only two participants.

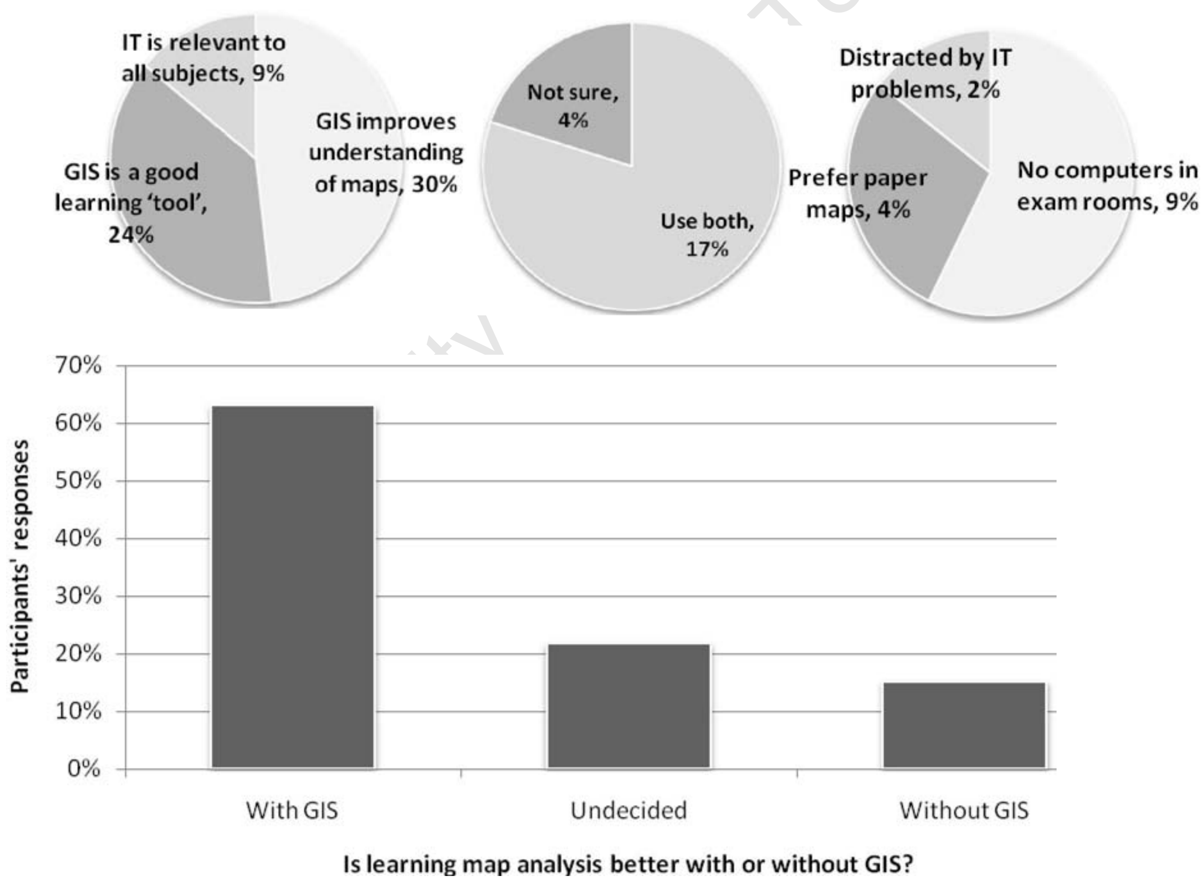


Figure 9.23 Support for using GIS to learn map analysis skills (bar graph), with the reasons that were given by participants (corresponding pie graphs) (n = 46)

9.7 LESSON PRESENTATION

An evaluation of how Microsoft PowerPoint was used to deliver the self-instruction programme was conducted as part of the closing questionnaire (Appendix 8.6). Eleven design elements used for the map skills lessons were described in Chapter Seven and are summarised in Box 7.2. Some elements refer to lesson administration and were not open for discussion in the questionnaire (e.g. title, why learn about the topic or what lesson comes next). The design elements common to all the lessons as well as the features that were used to enhance the digital presentation of the lessons were collectively referred to as lesson components in the evaluation. The GIS sub-lessons and GIS practical activities have already been discussed (in 9.6), other components of special interest are the glossary (in light of the concept learning difficulties in a multilingual society, as described by Block and Rollnick, 2003), the lesson text (providing the knowledge and the descriptions of the techniques required for each task) and the mathematics sub-lessons (because of the importance of mathematics instruction in map analysis as discussed in Chapter Four). Features of the PowerPoint presentation that enhanced the lesson text (also referred to as components of MapTrix Geomatica for the purpose of the questionnaire) were the animated illustrations (using the graphics options available in PowerPoint), sections with voice over (readings and explanations) and movie clips (mainly using screen shots to show where to find data layers and how to use the GIS tools).

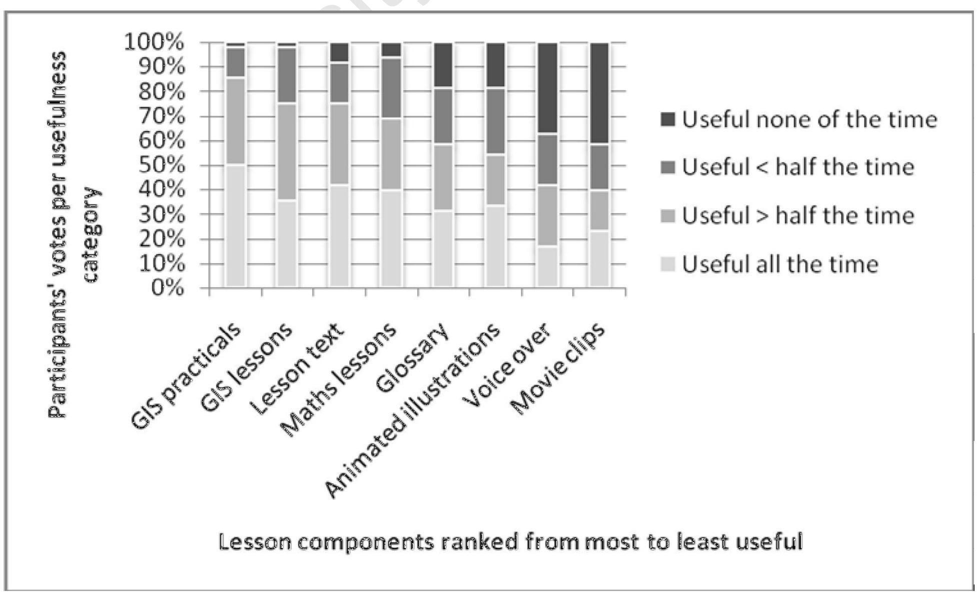


Figure 9.24 Trial participants' opinions (n = 48) of the usefulness of the lesson components in the MapTrix Geomatica prototype

The responses are coded according to usefulness (explained in Appendix 8.8); the number of times each code is returned is expressed as a percentage of the total number of responses for each lesson component. In Figure 9.24 components have been ranked using the responses for *useful all the time* plus *useful more than half the time* to indicate which components were considered the most useful by the participants.

As mentioned in Chapter Seven, the programme structure, lesson text, map selection and exercises and answers were developed first, while GIS was only later incorporated to deliver the learning materials. Yet the GIS components of the programme were considered to be the most useful. Of the participants who used the GIS practical activities, 85 % responded positively with 50 % considering them *useful all the time* and a further 35 % considering them useful *more than half the time*. The GIS sub-lessons were also rated favourably by 75 % of participants and the same percentage found the lesson text useful *all* (42 %) or *more than half the time* (33 %). More than half of the participants found the glossary (58 %) and animated illustrations useful (54 %). Based on these positive responses, the use of these components in the lessons of the final learning programme is assured.

The two components that participants rated as least useful were the voice-over sections and the movie clips. Participants' free responses to questions at the end of the questionnaire, asking what they thought should be left out and what else should be included, suggested reasons for their poor opinions of these two components. While the majority (70.2 %) indicated that nothing should be left out and 47 % indicated that there was nothing that should be added, the voice-over sections raised contradictory responses. The majority of the comments made by the 11 % who suggested leaving things out referred to sound, some indicating that it was too soft and others saying it was not necessary. In contrast, of the 23 % that made suggestions for additions to the prototype six participants specifically requested more voice-over (or 'reading to us') sections. In an interview with a female participant in the first trial group (Group SV) who did not have English as a home language, she particularly mentioned that the voice-over sections had been very useful and that there should be more.

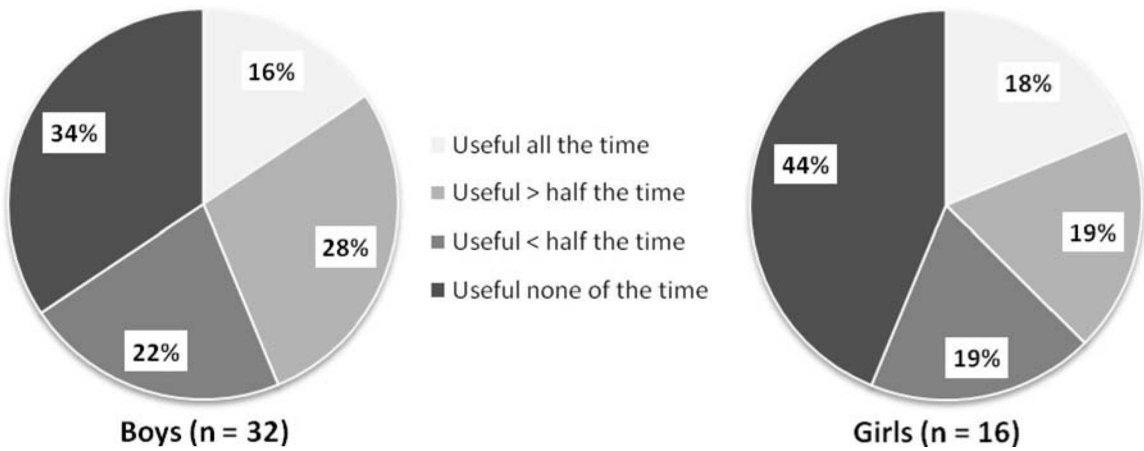


Figure 9.25 Percentage of males' and females' opinions of the usefulness of voice-overs (sometimes used with lesson text and/or animated illustrations) in the MapTrix Geomatica prototype

Further analysis was conducted to see if girls generally preferred to have the voice-over support. As Figure 9.25 shows, while proportionately more girls than boys thought the voice-overs were useful all the time, a greater percentage of the boys found the voice-overs useful more than half the time. Because there are twice as many males as females in the population sample and the total numbers are relatively small, the preference for voice-over support is not conclusively related to gender difference.

In order to demonstrate some of the GIS features and the use of the GIS tools, a series of screenshots highlighting the relevant buttons and actions were sequenced and animated. These movie clips also elicited less than favourable responses (Figure 9.24). They were mentioned in the free responses at the end of the closing questionnaire by a few participants, with as many suggesting leaving the movies out as adding more movies (4 % of responses each way). Specific comments about improvements to the movie clips for the profile lesson are included in the prototype product report (Appendix 9.1) Difficulties were experienced with downloading the appropriate version of the software required for viewing the movie clips at each of the trials. At the first trial with Groups SV and SS, the problem was resolved by the technical expert. With Groups PB and PI it took some time to download compatible versions of the software required for displaying the images. These delays may account for some of the frustration that led to the suggestions for exclusion of the movies.

9.8 SELF-INSTRUCTION

9.8.1 Interaction with others while using the self-instruction programme

MapTrix Geomatica provides learning resources which can be used by individuals to learn how to perform eight different map analysis tasks manually, using the GIS tools to check answers. Although the intention is that individuals can use the materials without assistance, during the trials there was no move to prevent participants from working together (except during the pre- and post-tests). Figure 9.26 illustrates the answers to an enquiry in the closing questionnaire regarding how much time was spent working alone on each lesson.

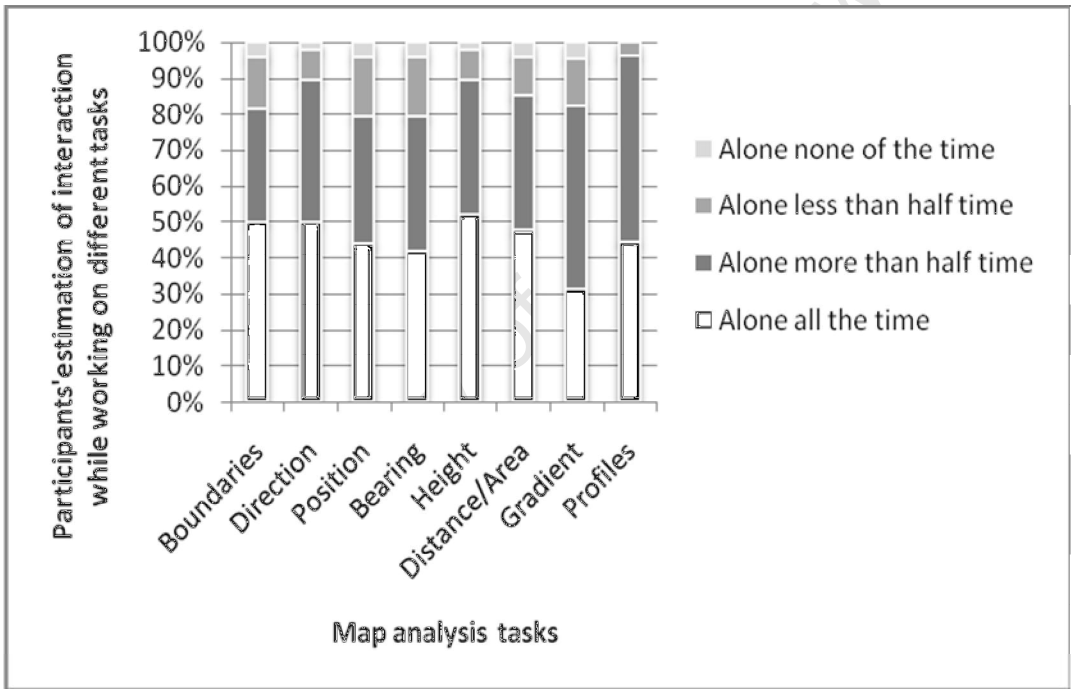


Figure 9.26 Interaction with others while working through the prototype MapTrix Geomatica self-instruction programme (n = 48 for the tasks on boundaries to distance/area; n = 45 for gradient; n = 27 for profiles)

The majority of participants estimated that they worked alone most or more than half of the time while a much smaller percent needed to work with someone else more than half the time or all the time. At the two ends of the scale, calculating gradient appeared to require most interaction; only 31 % of participants worked alone all the time on this task while 52 % estimated height without reporting interaction. From observation during the trials and from their responses it is clear that given the opportunity, a large percentage of learners prefer not to work in isolation.

When not working alone, participants were asked to estimate how much time was spent working with either a friend or with a teacher (i.e. the researcher or an assistant). The majority suggested that they received only a little help, either from friends or from the teacher (Figure 9.27). Of the 69 % requiring interaction while working on gradient, a teacher or friend helped equally. Bearing also required interaction with both teacher and friend. Distance/area and position required interaction but the teacher offered more help with the former and a friend more with the latter. While the role of the teacher when interacting with participants will be more fully described later, it focussed on explanations of content and techniques and demonstrations of how to perform manual tasks and to navigate through the programme. The role played by friends and classmates was somewhat different. Apart from limited discussion relating to the open questions about the practical use of spatial analysis skills and their relevance to the local environment, which were included at the start of each lesson, interaction focussed on working out the answers to the questions in the exercises.

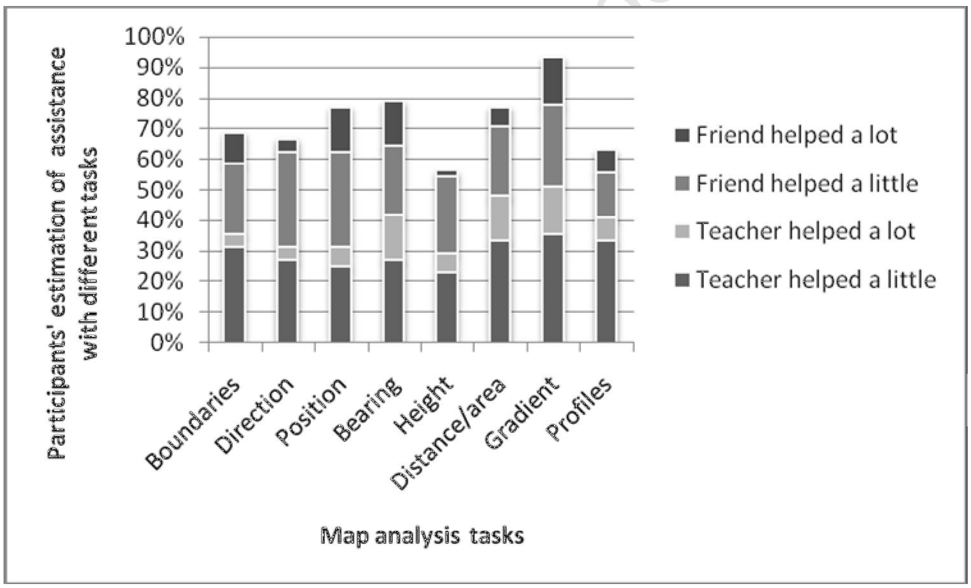


Figure 9.27 Assistance from others required while working through the eight lessons in the MapTrix Geomatica prototype (n = 48 for tasks on boundaries to distance/area; n = 45 for gradient; n = 27 for profiles)

9.8.2 Question answering strategies

In the original closing questionnaire there was only one enquiry related to question answering strategies. In their structured responses, of the 38 participants that admitted working with a friend, 29 % indicated that they had worked out the answers to questions themselves all the time, 55 % said that they had provided the answers themselves more than half the time, 11 % provided answers less than half the time and only 5 % admitted that they had not provided any answers and that the friend had done so for all exercises. During the first trial with Groups SV and SS it was observed that participants regularly discussed the answers. In order to investigate the question answering strategies used by the last two groups (PB and PI), Table A8.8.2 in Appendix 8.8 was included in their closing questionnaires (see second version of questionnaire in Appendix 8.6). Because markedly different attitudes had been displayed by these two groups, their responses are illustrated separately. Figure 9.28 reveals the strategies used by the 25 participants that completed this addition to the closing questionnaire.

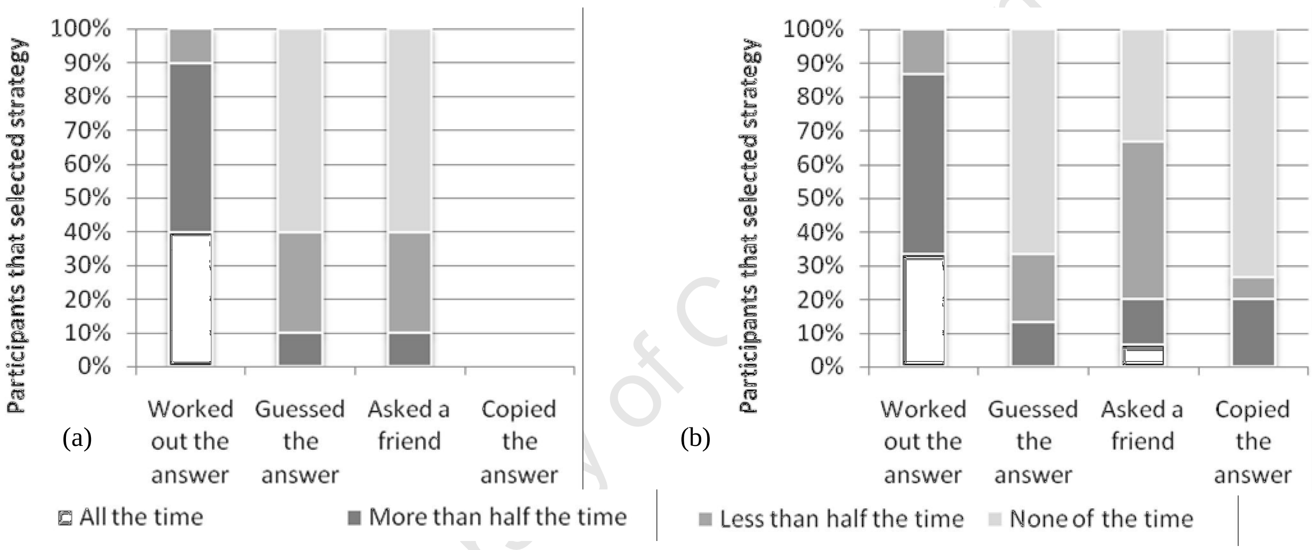


Figure 9.28 Strategies used by (a) Group PI (n = 10) and (b) Group PB (n = 15) for answering questions while working through the exercises in the prototype MapTrix Geomatica programme

Because they were following a self-instruction programme, it was anticipated that the majority of participants would *work out the answers* to the questions from the maps using the skills for which instruction had been given in the programme. This strategy was used by approximately the same percentage of participants in both groups. When combined, 36 % indicated that they did so all the time, 52 % indicated that they used the maps to work out the answers more than half the time, 12 % worked out the answer less than half the time and none indicated that they had not worked out any answers.

The less diligent alternative strategies were used differently by the two groups. In Group PI, 40 % admitted *guessing the answer* at least some of the time; while in Group PB, participants only guessed the answer 33 % of the time. Members of Group PI also relied on a friend for the answers 40 % of the time while in Group PB reliance on others in the class rose to 67% with 7 % of these having *asked a friend* for the answer all the time. No members of Group PI indicated that they had *copied answers* whereas in Group PB 27 % admitted doing so at least some of the time.

9.8.3 Answer marking strategies

An important part of a self-instruction programme is the immediacy of feedback. Because of the past reliance on marks in traditional norm-referenced teaching, the terminology preferred in South African schools for checking answers is *marking* answers. The accuracy of self-assessment has been discussed in 9.5 where it was found that participants generally over-estimated their scores when marking their exercises. Apart from this general trend, answer marking strategies specific to the two private school groups were gleaned by the addition of questions (as discussed in Appendix 8.8) to the second version of the questionnaire survey (Appendix 8.6.ii).

Group PB did not mark their own answers from the third lesson (position) onwards. Because the teacher in charge suspected they would cheat and copy answers, he disabled the link to the answer screens in the programme (which the other groups had used for marking their answers). Marking memorandums were downloaded and printed. These were provided to each boy in Group PB as he finished an exercise so he could mark his answers. After the first two lessons it was clear that these model answers were being circulated and copied. From that point on, the answer sheets were collected and marked by the researcher. Because some members of this group had proved to be uncooperative, answer sheets were not returned to them for fear of losing the valuable data they contained, for this reason they did not have the advantage of feedback.

Participants in Groups PI were asked whether they liked marking their own answers and why. The boys in Group PB were given the opportunity to indicate whether they would have liked to mark their own answers. The contrasting responses of the two groups are illustrated in Figure 9.29. Only one participant in Group PI indicated that they would prefer not to have marked their answers, citing this as the teacher's responsibility. The majority preferred marking their answers because they enjoyed the positive reinforcement and recognised the benefit of learning from their mistakes. In contrast, only three in Group PB would have preferred to mark their answers as they would learn from their mistakes and three felt that the teacher should mark for them. The majority of boys did not want to mark their answers, proving the teacher's suspicions correct by indicating they might cheat. This reinforces the findings in Figure 9.28 where 27 % admitted cheating by copying answers.

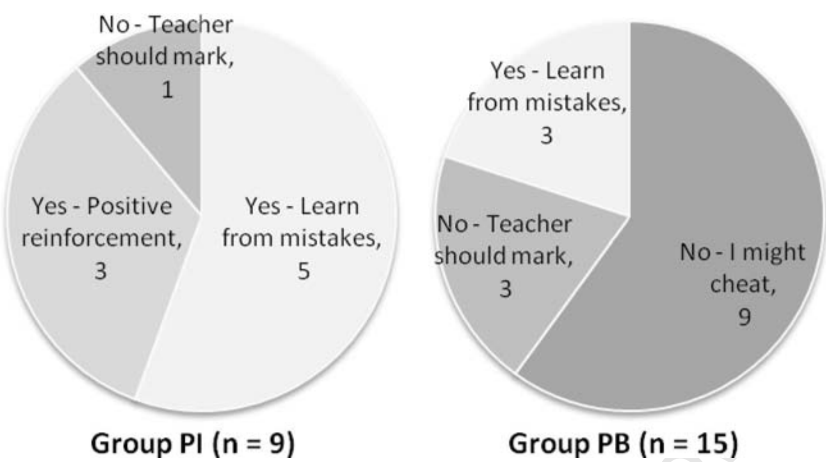


Figure 9.29 Comparison of self-assessment preferences of the two private school groups who trialled MapTrix Geomatica

9.9 EVALUATION OF PARTICIPANTS' ATTITUDES TO MAPTRIX GEOMATICA

A key question in the closing questionnaire enquired whether the prototype of the MapTrix Geomatica programme had met its objective of improving map analysis skills. A *yes* response was returned by 95.7 % of participants indicating that despite time constraints and minor errors and reservations, the majority agreed that the programme had met its objective.

Also in the closing questionnaire, an opportunity was afforded to indicate whether anything should be added or left out of the programme. 89 % made no suggestions for removing anything, of the 11 % who suggested removing features, a small number referred to the questions designed to stimulate interest in spatial issues related to the learners' local environment, others suggested leaving out entire lessons (e.g. bearing). 81 % indicated no shortfalls, suggestions given by 19 % of the respondents for inclusions referred to more maps, more data, more examples and more sound (already referred to in 9.7). One suggestion worthy of consideration was the inclusion of oblique aerial photographs to illustrate geographic features. Much of the additional learning content that was suggested (e.g. vertical exaggeration of profiles and magnetic bearing) and requests for more interpretive questions are already planned for the second phase of the programme (see the unshaded sections of Table 7.1). These additional lessons and exercises will address more advanced activities to assist learners progressing towards the last year of the FET phase.

The results of the post-intervention attitude survey included in the closing questionnaire are illustrated in Figure 9.30. The scoring protocol, based on participants' free responses, is described in Table A8.8.3 in Appendix 8.8. Six participants used words to describe the programme that indicated a slightly negative attitude, two were neutral and the rest (36) described the programme in words that ranged between neutral to strongly positive. Two participants who used words to describe the programme that accumulated the maximum positive score were the two geography teachers who participated in the trial with Group SV.

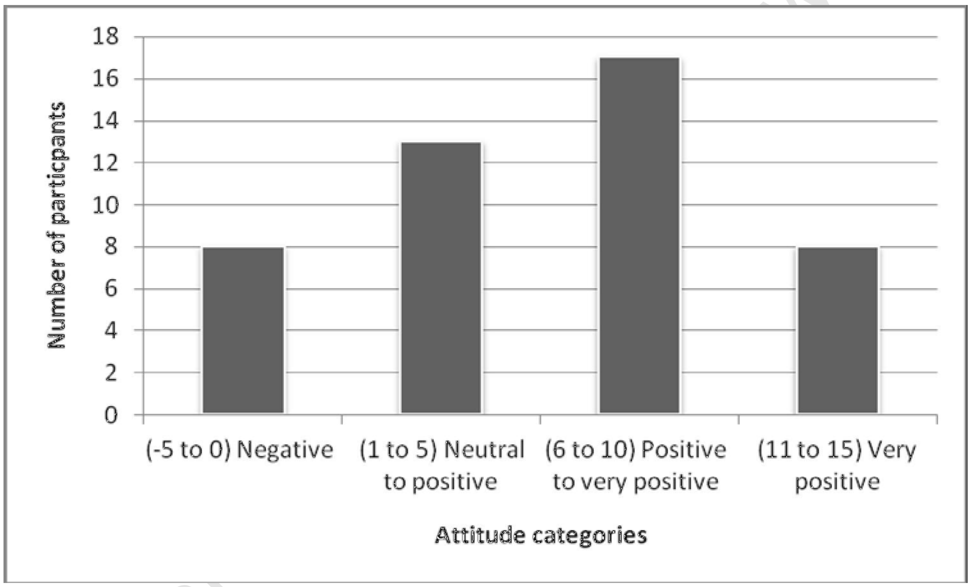


Figure 9.30 Results of post-intervention attitude rating score for MapTrix Geomatica (n = 44)
-15 = maximum negative attitude, 0 = neutral, +15 = maximum positive attitude

9.10 CONCLUSION

The hypothesis supported by the findings in Chapter Seven is that it is possible to develop a self-instruction programme for map analysis and to use a GIS to deliver the learning components. The analysis of data gathered during the evaluation of MapTrix Geomatica that is described in this chapter supports the main hypothesis of the thesis which is that self-instruction, using GIS, can improve map analysis skills. A large dataset has been analysed, the findings described and where possible explained by the results of further data analysis. The validity of the three assumptions about GIS (itemised in 7.1.3), upon which the central hypothesis rests, is assessed in the final Chapter. Some findings in this chapter are discussed further in Chapter Ten and conclusions are drawn as to the extent to which the hypothesis supports the main argument of the thesis. Recommendations for improvements to the programme are made and guidelines for teachers who might implement such a self instruction programme for map analysis are suggested.

CHAPTER 10

DISCUSSION, RECOMMENDATIONS AND CONCLUSION

Spatial thinking can be learned, and *it can and should be taught at all levels in the education system. With advances in computational systems (hardware and software), spatial thinking can now be supported in ways that enhance the speed, accuracy, and flexibility of its operation and open up the process to increasing numbers of people, working collaboratively and at higher levels of performance.*

(NRC, 2006, 3)

10.1 INTRODUCTION

The purpose of this research is to develop and evaluate a self-instruction programme for analysing spatial information intended to support geography education in South African secondary schools. The need for such a programme was identified in Chapter One where the widespread problem of poor map skills (Magi, 1981; Sekete, 1995; Tshibalo, 2003) was illustrated by analysing the geography practical matriculation examination results for 2000 to 2007 (Figure 1.4). These poor results are linked to the history of geography teaching (Clark, 1989; Wesso and Parnell, 1992) offered to the majority of South Africa's population under the former apartheid education policies (Kallaway, 1984) which has impacted negatively on the standard of education and training received by many teachers currently teaching Geography.

In Chapter Two the literature on three aspects of enhancing spatial competence was investigated: how cognitive maps inform spatial behaviour (from early studies by Griffin, 1973; Lynch, 1973 and Lee, 1973 to more recent work by *inter alia* Tversky, 1993 and 2005), how cartographic maps represent the world (from suggestions by Muehrcke, 1978; Gerber, 1984; Downs, 1985; Ottoson, 1988; and relative to digital maps, MacEachren, 2004; Bunch *et al*., 2008) and how the real world is perceived and comprehended (reviewed by Cohen, 1985; Sternberg, 2005; Scardamalia and Bereiter, 2006). The contribution of enquiry-based learning to geographic understanding was stressed (Naish *et al*., 1979 and 2002). The potential of GIS for enhancing spatial comprehension through improved visualisation technology was discussed (Eastman, 1985; Brooke, 2001; MacEachren, 2004), supporting the decision to use GIS as a delivery mechanism for spatial competence learning materials. Another reason is the inclusion of GIS in the NCS for Geography (DoE, 2003, 2004, 2005 and 2007) although the lack of guidance for progressing spatial skills in these documents, and the more recent ones (DoE, 2008a and 2008b) was noted.

The results of investigations in Chapter Three on *MapTrix* (based on work by Innes, 1998 and 2000) and Chapter Six, on educator competence, support the use of self-instruction to improve both learners' and teachers' spatial skills in a resource poor environment (Liebenberg, 1998; Chisholm, 2005). Investigations in Chapters Four, on the influence of Mathematics instruction on map analysis skills (Castner, 2002a and 2002b) and Five, on realistic workplace expectations (Stott, 2004) in South Africa, directly informed the content and compilation of the GIS-enabled prototype self-instruction programme for analysing spatial information. The design (Anderson, 1997; Moallem, 2001) and components (Gagné and Briggs, 1974; Alexander and Blanchard, 1985) are discussed in Chapter Seven along with the arrangements for trialling the programme (Cohen and Manion, 1985; Huysamen, 1994). The use of the MapTrix Digital Game for map reading, to prepare the trial participants for the next skill level - map analysis (as discussed in Chapter Eight) is in keeping with the map skills hierarchy as outlined by Boardman (1983) and Castner (2002a and 2002b). The culmination of the research is the analysis of the data (with guidance from *inter alia* Ebdon, 1985) collected in the MapTrix Geomatica trial, which is the focus of Chapter Nine.

In this chapter the findings of the data analysis are evaluated to establish whether the aims and objectives of the research have been met. As discussed in Chapter Seven (7.2), the MapTrix Geomatica programme has been developed using the behaviourist model of instructional design because the goal is skill development. Stott’s (2004) model for evaluating instructional design for learning material in the GIS environment in South Africa emphasises the constructivist model for instructional design which is recommended in order to foster higher-order thinking skills - including spatial thinking (NRC, 2006). Although the paradigms are different, Stott's Instructional Design Model Evaluation Elements (adapted in Figure 10.1) are useful for structuring the discussion that follows which seeks to answer five questions:

- Does the MapTrix Geomatica programme for analysing spatial information work?
- Does self-instruction really work and do teachers have a role?
- Does GIS work as a means to deliver an introductory spatial analysis programme?
- How can the findings of the MapTrix Geomatica trials be used to improve the effectiveness of the programme?
- What are the wider applications of the findings?

Stott's (2004) evaluation of GIS instruction models focuses on three issues: the theoretical framework within which the instruction model was developed, the context within which the model is used to develop an instruction programme and the implementation of the programme. The theoretical framework includes the nature of the knowledge to be acquired (epistemology) and how the learning takes place (pedagogy). The context in which the learning takes place includes the learning environment and the role of the teacher.

The central element in her evaluation approach is the interactive learning made possible by the computer-based implementation of the programme. It is the evidence of that learning which is the starting point for the discussion that follows – using the scores for the map analysis pre- and post-tests (Appendix 8.4) and for the 16 MapTrix Geomatica exercises (example in Appendix 8.5).

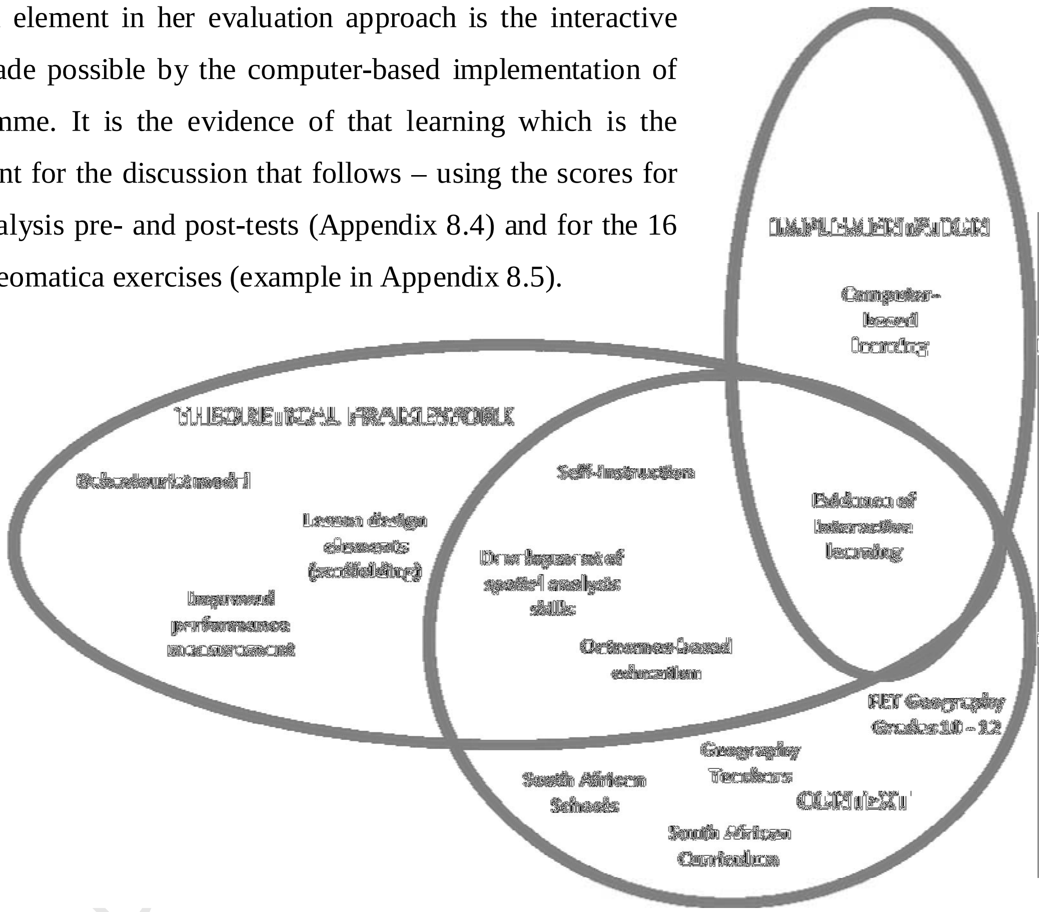


Figure 10.1 Framework for evaluating the design and components of MapTrix Geomatica (adapted from the Instructional Design Model Evaluation Elements diagram of Stott, 2004: 63)

10.2 MAPTRIX GEOMATICA IMPROVES MAP ANALYSIS SCORES

10.2.1 MapTrix Geomatica impacts positively on map analysis scores

The results presented in Chapter Nine (Table 9.2) show conclusively that the innovation, which is a self-instruction, computer assisted, GIS-based, learning programme, can significantly improve map analysis competency in school learners (Ritchhart and Perkins, 2005). Accepting that the mental ability of every individual is modifiable (Feuerstein *et al*., 1988), is the starting point for developing a programme of enrichment to mediate learning experiences; their guidance has particular relevance in a multi-cultural setting, such as the South African classroom (Skuy, 1993). To introduce new spatial competence learning within a cumulative skills hierarchy (Boardman, 1983 and following; Ormeling, 1996a and 1996b) and then structure each unit of learning so that it has relevance to the learners' cognitive needs and can be delivered at their individual pace (Gagné and Briggs, 1974; Alexander and Blanchard, 1985) was the overriding aim of MapTrix Geomatica. The hypothesis that self-instruction, using GIS, can improve map analysis scores can be accepted, and accordingly, the aim of the thesis has indeed been met.

In the evaluation of the prototype of *MapTrix* (Innes 1998), map reading scores increased and map reading time decreased indicating that self-instruction had improved both accuracy and efficiency. While increased mean scores in the map analysis post-test indicate that the intervention was successful (Table 9.2), the improvement was not necessarily accompanied by greater efficiency because participants took longer to complete the post test than the pre-test. On investigation it was found that a large number of the participants had simply left out answers in the map analysis pre-tests, whereas, more participants had attempted the answers to more of the questions in the post-test, thus taking longer to complete the test. This suggests that the intervention had increased learner confidence sufficiently for them to attempt more of the answers. Longer exposure to the interactive learning made possible by the programme, certainly more time than was possible under trial conditions, would probably reduce map analysis post-test times and indicate greater efficiency.

Comparison of mean scores for the individual map analysis tasks showed that, although there was overall improvement, this varied according to task. There were very low pre- and post-test scores for mathematically challenging tasks, e.g. estimation of altitude and calculation of distance or gradient, but when the difference between the pre- and post-test scores for these tasks was calculated as a percentage of the pre-test score, the gain scores were in the order of 97 %, 320 % and 300 %, highly significant improvements, albeit off a low base. A number of computer-assisted mathematics skills programmes have recently been introduced to schools by the Khanya Project of the WCED (Matandela, 2008). The potential of these programmes to improve the skills needed for map analysis could be investigated and the results used to improve the mathematics sub-lessons in MapTrix Geomatica.

10.2.2 Impact of gender on map analysis performance

It is widely argued that males are more spatially competent than females, both in popular psychology (Pease and Pease, 1999) and in cartographic and spatial thinking research (Linn and Petersen, 1986 *inter alia* and, more recently, Liben and Bigler, 2002). Such competence would in part relate to an ability to analyse spatial information. The results here suggest that, while there was indeed a significant difference between pre-test scores of the male and female participants, the differences between their post-test and improved scores were not statistically significant (Table 9.3). Accordingly, the programme would appear to be suitable for both male and female learners. These findings are encouraging in the light of the gender bias in attitudes to computers reported by Colley and Comber (2003) who found that female (especially older females at secondary school) had a more negative attitude to computers than their male counterparts.

10.2.3 Impact of home language on map analysis performance

South Africa is multi-lingual (there are eleven official languages) but at secondary school level Geography is taught in only two of these languages – English and Afrikaans. Matengu (2006) makes specific reference to the dominance of English in the ICT realm and suggests that this limits access to many whose home language is not English. It was therefore anticipated that English (or English and Afrikaans) speakers would outperform other groups (Figure 9.6). In fact, improved performance in the only isiXhosa speaker in the study was not significantly different to those with English as a home language. This may be explained by the fact that geographic terminology is framed in English and would, therefore be automatically familiar to the isiXhosa speaker (who was at an English medium school). The lack of improvement of the three non-SA language speakers can be related to their high pre-test scores, possibly suggesting that in their countries of origin, they may have received more effective map use training at a younger age? In light of the importance of language in geography learning (Brown and Palincsar, 1982; Butt, 2002) the small degree of improvement in the Afrikaans speakers suggests that translation of the programme, or at least of the glossary, would benefit non-English speakers.

10.2.4 Impact of age on map analysis performance

In England and the United States, education systems are age-graded because chronological age is closely associated with many aspects of thinking and learning (Piaget, Vygotsky and Bruner *loc.cit.* NRC, 2006). In the South African education system, norm referenced assessment was used (until recently) to progress learners from one grade to the next. This means that slower learners were kept back with younger learners to repeat grades. This makes it difficult to relate skill levels to learners of specific ages. In this study, scores appeared to decline with age in the sampled population (Figure 9.7). Similar results were found during the trials of the prototype of *MapTrix* (Innes, 1998). These findings reflect the observations of Naish (1982) that not all learners develop at the same pace and that some individuals never reach the stage of formal operational thought, which is marked by the development of representational concepts as required when working with maps. It can be anticipated that, with additional mediation from a trained instructor and more time to use all programme components, older learners would eventually benefit from the alternative teaching methodology of MapTrix Geomatica.

10.2.5 Impact of access to computers on map analysis performance

Learners with the lowest level of access to computers had the lowest scores and that those with the greatest access had the highest scores (Figure 9.8). This may of course relate more to socio-economic factors than map skills *per se*. Matengu (2006) found that poverty was one of the main barriers to computer access and was also associated with deprivation in other areas such as quality of education. Lack of IT skills may have hampered the progress of those with limited access to computers who scored badly. Again, more opportunity to use the programme could probably enhance map (and IT) skills.

There was no significant difference between the mean scores of those who had an IT elective and those who did not, as reported in Chapter Nine (9.4.4). This may be due to the fact that the majority of the participants were in Grade 10 and would only recently have started their IT course at FET level. They would not yet have progressed to using software of the complexity of GIS. They therefore had no advantage over the non-IT participants. It may also suggest that the simplicity of the programme design, which uses GIS to deliver the learning materials rather than teaching the intricacies of GIS, poses no problems for those without specific IT training.

10.2.6 Impact of school subject combinations on map analysis performance

It has been recognised that there are content areas and skills in both Mathematics and Science in which performance is related to (and might support) the development of spatial thinking (NRC, 2006). Map analysis clearly involves a range of mathematical operations. The Learning Outcomes and Assessment Standards for all subjects (other than Geography) across all grades at FET level

(DoE, 2004) were examined to find references to map use. Although maps are mentioned in Mathematics (and occasionally in Travel and Tourism and Language studies) no evidence was found that the education policy documents highlight specific ways in which Mathematics and Geography teachers might co-ordinate their efforts to teach Mathematics for map users and so improve spatial competence.

This study reports that first year students who had previously taken Geography for matriculation performed better at map *reading* tasks than those who had taken Mathematics without Geography (Chapter Four, Figure 4.3). Those who had taken Mathematics, however, performed better at map *analysis* tasks than those who had taken Geography without Mathematics. Students who had taken both Mathematics and Geography outperformed those with any other subject combination that included Mathematics, Science and Geography.

In the MapTrix Geomatica trials, it seems Science was a better indicator of good map analysis skills than Mathematics (Figure 9.11). Highest scores were attained by those with Mathematics, Science and Geography and lowest scores attained by those with Mathematics and Geography but no Science. This could be because the level of Mathematics taught up to Grade 10 does not provide learners with the mathematical competencies required for map analysis tasks. It is a personal observation that Science is generally offered as an elective subject to those who are considered to be the more academically able learners. Learners with Science, Mathematics and Geography electives completed the self-instruction programme faster and with better scores than other learners in this study. Those without these supporting subjects may need more time to use all the teaching components of the programme and to complete both exercises on each lesson to reach the same level of achievement.

10.3 THE SELF-INSTRUCTION METHODOLOGY

10.3.1 The teacher’s role in the MapTrix Geomatica trials

During the first trials held in the computer laboratory at the University of Cape Town the researcher and two assistants fulfilled the roles of *teachers* for the *learners* who participated. At the start of the intervention, background information about the research project was given to participants and the GIS software was introduced using guidelines provided by the consultant who adapted the programme for the GIS platform (Appendix 7.6). Other functions included: managing the resources that were required by the participants, trouble-shooting technical problems, answering questions (about various matters including content issues and terminology) and assisting with navigation between the GIS and PowerPoint components of the MapTrix Geomatica programme. Files were maintained for each participant to keep all data collection instruments in order. Participants were observed and assisted whenever they became confused or anxious.

Unfortunately, the order of the lessons on the opening screen was incorrect (Figure 7.1). This was pointed out to participants at the start of the intervention and the correct lesson order was displayed. Some participants dismissed this information. Tackling exercises in the wrong order caused them difficulties because they had not acquired the necessary skills in the correct sequence. The importance of following a skills hierarchy (initially illustrated in Figure 4.1 and later refined in Table 5.6) had to be carefully explained.

From repeated requests for assistance with the same issues, other errors in the programme were identified (see Appendix 9.1). Some of these issues related to incorrect information in the lessons, some to answers that did not match the questions. When preparing the exercises, paper copies of the latest editions of all the topographic maps had been acquired. It was only discovered during the first trial that the digital versions of some of the maps that had been imported into the GIS programme, were of older editions. In some cases, questions referred to features not shown on the maps causing confusion for the participants. While such issues would be minimised in the final version of the self-instruction programme, errors cannot be ruled out and teachers should be familiar enough with any LTSM to avoid confusion and to put learners at ease.

When it was decided to abandon the MapTrix Geomatica trials at the first school that offered their facilities (Group SX), one of the teachers suggested that, had they been trained in the use of the programme beforehand, they might have been able to assist in moving at least some of the learners on to the programme. The assistance of the teacher who was already familiar with GIS at the second school (Group PB) and the technical expertise of the IT teacher at the third school (Group PI) were a great help. It is clear that, in order to run the self-instruction programme, teachers should receive training in both the use of MapTrix Geomatica (including the basics of GIS) and in managing the resources related to the programme. Under the guidance of a trainer, MapTrix Geomatica can be used to facilitate that training against the theoretical background illustrated in Figure 10.1.

10.3.2 Accommodating differences in learning environments

A self-instruction programme aims to teach unique individuals with different abilities at their own pace and under different circumstances (Gagné and Briggs, 1974). The impact of the different characteristics and circumstances of individuals on the trial outcomes has been discussed (section 10.2). When comparing the mean pre- and post-test scores for map analysis of the four Groups that participated in the trials, interesting - if statistically insignificant - differences can be identified (Figure 9.3). The different environments in which the groups trialed the programme are examined to identify the conditions that may facilitate more effective use of the programme.

Both volunteer groups of learners from state schools who used the computer facilities at the university during the holidays had similar mean pre- and post-tests scores (Figure 9.4). Group SV, who selected computer sessions as it suited them over a nine day period, had the highest post-test score of all groups. This was the most heterogeneous group, coming from different schools (as illustrated in Table 7.2 and Figure 7.4), differing widely in age, speaking a variety of home languages and having very different levels of access to computers. Their common characteristic was their preparedness to give up school holiday time to attend a map skills course and, as there was no rush to finish, they could follow all lesson instructions and complete more than one exercise per lesson to improve their skills (if necessary) before writing the post-test. They also had a very positive attitude to GIS (Figure 9.22). Many of these characteristics were shared by Group SS who completed the programme over two and a half days. However, their mean post-test scores were lower (Figure 9.3), probably because they had to work within such tight time constraints.

The boys from the private school (PB) had the highest pre-test scores but the lowest post-test scores and thus showed the least improvement (Figure 9.4). They were the most homogeneous group, all had English as a home language and each had their own laptop. Their negative attitude to GIS (Figure 9.22) which was linked to previous experience with the software (according to their teacher) and the fact that they did not complete all the exercises contributed to their disappointing lack of improvement.

Group PI at the private international school showed the greatest improvement (Figure 9.4) despite the fact that the trials were condensed into only two days (excluding completion of questionnaires and pre- and post-testing time). Learners worked diligently and although few took the opportunity to do more than one exercise per lesson, they all completed at least one. Although not all were currently taking Geography as a school subject, all had access to computer facilities and an interest in learning new software (GIS).

10.3.3 Attitude of participants to self-assessment

The contrasting attitudes to self-assessment evidenced in Figure 9.29, mirrors contrasting education philosophies. Because the learners in Group PI were accustomed to self-assessment in their school system and especially in the classes of the science teacher who had arranged the trial (Appendix 7.5), they are not short-term mark driven. Marks are less important than attaining understanding and competence. The tendency of participants in Group PI to work out the answers to the questions in the exercises, record them and then assess them honestly may be the reason that their exercise scores were consistently lower than the scores for other groups as illustrated in Figures 9.16 and 9.17. In contrast to the outcomes based education (OBE) focus recently introduced in South African schools, they do not accumulate marks for continuous assessment. The evaluation of their progress relies solely on external examinations which require high levels of cognitive skills, developed by taking personal responsibility for their own learning. Group PI's improvement in spatial analysis competence, as evidenced by the difference between their pre- and post-tests scores, was significantly greater than the improvement of any of the other Groups (Figure 9.4).

In a discussion with the teacher in charge of Group PB it was discovered that rigorous, regular testing is carried out at the school with a strong emphasis on earning high marks. Apart from the emphasis on the accumulation of marks for continuous assessment, failure to attain predefined marks leads to punishment in the form of detention or curtailment of privileges. The teacher also suggested that many of the boys in the test group are in the habit of focussing on how to attain enough marks to avoid punishment rather than on using their energies to attain mastery over concepts and skills. The avoidance behaviour that some boys displayed by not ensuring that their laptops (or the software) functioned correctly could, perhaps, have been an attempt to avoid presenting work for marking (Appendices 7.4). Some of those who preferred not to mark their own work transferred responsibility for their learning onto the teacher while others admitted to cheating (Figure 9.29). The result of their being mark-driven rather than mastery-motivated, coupled with not benefitting from the feedback provided by self-assessment, is that their level of spatial skills improvement was significantly lower than any of the other groups (Figure 9.4).

10.3.4 Self-assessment challenges for teachers

Stiggins (1994) found that self-monitoring, of which self-assessment is a component, is an effective means to develop learners' metacognitive awareness. In traditional learning environments learners' progress is assessed, monitored and communicated by the teacher with very little detail shared with learners (or parents). Learner-centred communication, on the other hand, focuses on more than just marks - ratings, narrative reports and the accumulation of evidence of progress in portfolios of learners' work are added. In the self-instruction learning model that was used to develop both *MapTrix* and MapTrix Geomatica the learners self-assess, generating the marks by which their learning is measured, thereby monitoring their own progress toward achievement goals, as recommended by McCown *et al*. (1996).

In their answers to the MapTrix Questionnaire, teachers responded positively to the self-instruction methodology (Table 3.10) which is in turn closely linked to OBE. However, Beets and Le Grange, (2005) point out that South African teachers face many challenges in moving from traditional teaching methods to OBE, not the least of these is adapting their practice to accommodate outcomes-based assessment (Maree and Fraser, 2004) where marks are no longer an end in themselves but are used as a means of demonstrating competence in an environment of high learning expectations where there are '...no restrictions placed on the number of learners that can be successful' (du Toit and du Toit, 2004:5). The 80 % mastery indicator adopted as a performance benchmark in both self-instruction programmes (for map reading and map analysis) is a far cry from the low bench mark set by examination pass marks which traditionally indicate adequate performance.

Honesty and accuracy are important targets for teachers facilitating the self-instruction method. As illustrated in Figure 9.14, the participants in the MapTrix Geomatica trials generally overestimated the accuracy of their answers. Confident that they had attained (in their own evaluation) high exercise scores, they appear to have paid scant attention to accuracy when answering the post-test. Another concern is that participants with unjustified high scores assume that they have the ability to perform a task to an adequate level of accuracy and remain unaware of the need to spend more time either to improve their skills or to correct misunderstandings of techniques or concepts.

While the mean over-estimation of scores was only five percent, some participants consistently and dishonestly inflated their scores to a greater degree (Figure 9.14). Teachers must be aware of this possibility when using the self-instruction method especially if the self-assessed scores presented by learners are to be used as part of the continuous assessment of their progress. Sometimes errors are made due to inexperience with self-assessment rather than dishonesty *per se*. It is the responsibility of the teacher to train learners in self-assessment skills to ensure that the benefits of this learning mode can be made available to them.

Teachers should be alerted to the fact that learners may select different strategies for finding answers to questions (Figure 9.26). Although self-instruction is desirable, perhaps pairing learners at a computer terminal may benefit learners who need affirmation to gain confidence before going on to work alone later. Learners also have different working styles, ranging from working impulsively (fast and inaccurately) to working reflectively (slowly and accurately) with a range of variants in between (Kagan, 1964a; 1964b) as discussed in Chapter Four (4.4.3). Rather than abandoning learners to teach themselves using the programme, teachers will need to observe them closely, try to identify their individual learning styles and offer them appropriate mediation.

In Figure 9.29 the difference between the attitudes of Groups PB and PI to self-assessment are illustrated. They indicate the range of opinions that teachers may have to deal with in the classroom. Teachers must be alerted to identify outright cheating and to discourage this practice in the learners' own interests. When copying an answer from an answer sheet or from a fellow classmate, no learning takes place. Correct answers, honestly generated, are indicators of mental processes of comprehension and provide evidence of inter-active learning (Stott, 2004) – a cornerstone of the self-instruction methodology.

10.4 GIS DELIVERY OF AN INTRODUCTORY SPATIAL ANALYSIS PROGRAMME

Many school GIS initiatives promote the use of the mapping function (English and Feaster, 2003). GIS use in this investigation is confined to aiding visualisation by guiding learners to identify their location, to zoom in and out of matching ortho-rectified satellite images, aerial photographs and geo-referenced topographic maps and, with a digital terrain model (DTM) backdrop, to overlay contour lines, climate, infrastructure and administration data. They then return to paper topographic maps to execute selected spatial analysis tasks manually. The importance of using local maps (Sandford, 1980 and following) was acknowledged by using the topographic map extract covering the trial area (Figure7.4) for the pre- and post-testing (Appendix 4.1).

That GIS enhances visualisation is taken as given (van der Schee, 1989, 2003, 2006). This is because GIS software can present multiple visual layers of information about the local area or other places (such as maps, geo-referenced aerial photographs, satellite images that enhance various surface attributes, DEMs etc.). A GIS is a complex combination of hardware and software used by a number of educators to engage learners in valuable learning experiences (Appendix 2.1) that meet all the goals of the *International Charter on Geographical Education*. A wide range of GIS tools and techniques are available (Casti, 2005), but are they all necessary, at school level, especially when first introducing GIS? In situations where IT facilities are limited - where there is no automatic real time connectivity to the internet for downloading datasets, or where available personal computers have limited memory and processing capacity - it is still possible to use those functions that enhance spatial competence. The digital video disc (DVD) (de Sousa *et al.*, 2006) provides an alternative means of delivering at least some aspects of a GIS, including a digital atlas and processing functionality to address basic spatial learning needs.

It is also widely accepted that, while GIS is certainly useful, it is not at present being used to its full potential for enhancing spatial competence (Newell, 1997; Baker and Bednarz, 2003; Bednarz and Bednarz, 2008). Even where hardware is available, teachers are not trained in the use of GIS itself nor in the application of the pedagogical imperatives for using the technology for spatio-cognitive development (Bunch *et al.*, 2008).

A third given is that, for the foreseeable future, despite encouraging education policies (cited by Lundall and Howell, 2000; Howie *et al.*, 2005), learners of Geography at school level in South Africa (and probably many other countries) will be assessed on their ability to analyse spatial information using paper maps. It is suggested that only limited GIS functionality be used to enhance spatial competence while still employing paper maps, and at the same time to introduce learners to the basic concepts and functionality of GIS.

GIS may indeed be an efficient strategy for developing spatial thinking, but it involves complex software and '...teachers question the value of investing in the instruction time necessary for students to attain a level of proficiency that allows them to solve interesting problems with the tools' (NRC, 2006: 19). The complexity of the software was suggested as a reason why the boys in Group PB already had a negative attitude to GIS having received initial exposure to a complex, industry-based software package that had been adapted for education. By introducing GIS functionality in very small increments and initially only those functions that were required to find, link, view and zoom into data layers and then only those GIS tools required for eight basic spatial analysis tasks, the majority of participants made confident progress, i.e. one small step at a time. Indeed, most indicated a willingness to learn more about GIS (Figure 9.22) and were able to identify advantages of using GIS over paper maps (Figure 9.21) and give reasons why learning map analysis skills with GIS was better than without GIS (Figure 9.23).

This formative evaluation of the prototype was conducted to assess whether the self-instruction method could be used to improve map analysis skills at an introductory level (corresponding with Grade 10), using 16 of the 52 *MapTrix* map extracts. The more complex B lessons and exercises, illustrated in Table 7.1, have already been written (for Grade 11 level). These will require more advanced GIS sub-lessons and will offer a further 20 exercises for practising more advanced map analysis skills. It is proposed that ultimately the programme will include map interpretation lessons (for Grade 12 level) and an accompanying array of 16 more exercises. This will make up the 52 exercises corresponding with a pack of playing cards used as the organising structure of both *MapTrix* (Table 3.2) and the MapTrix Geomatica prototype (Table 7.1). These advanced map skills lessons will require further accompanying GIS sub-lessons that encourage relatively complex spatial thinking. Development of the advanced spatial skills will require use of the constructivist model of instructional design, more suited to teaching high level cognitive skills (Jonassen, 1992) and ideally should include representatives from all stakeholders in a participatory design team (Wilson *et al.*, 1995).

10.5 PROGRAMME IMPROVEMENTS

10.5.1 Recommendations per lesson following the MapTrix Geomatica trials

Errors have been identified in the lessons and exercises and have been reported in Appendix 9.1. Apart from these oversights, the design of each lesson and each exercise was evaluated using learners' exercise scores and responses to the opinion survey. Because the easiness rating score per skill that was derived from the participants' pre-intervention opinions (Figure 9.18) was calculated differently from the post-intervention rating (Figure 9.19), these easiness scores cannot be directly compared as with the pre- and post-test scores. However, changes in perceived easiness of one skill relative to another are detectable, suggesting where strengths and weaknesses in the programme may lie. The data presented in Figure 9.17 underpin many of the following recommendations.

- Boundaries

Participants realised that boundary identification was not as difficult as they had assumed prior to the intervention. The easiness rating (Figure 9.18) went up appreciably (to 96 %, Figure 9.19) but there was not much improvement in the score, which was already the highest in the pre-test although it still improved by 3 % to 73 %. Unfortunately the evaluation of map analysis skills relative to boundary recognition did not include an evaluation of the participants' ability to interact with the GIS software which was introduced during this lesson. It is interesting to note that only Group PB, which was already familiar with GIS, showed a significant improvement in this skill (Figure 9.17). Other groups showed a small improvement or their scores declined. This may be related to their initial lack of familiarity with the computer assisted learning environment and/or the GIS software. Generally the high scores for this skill confirm its place at the easy end of the skills hierarchy.

- Direction

No participants identified the direction lesson as difficult either before the intervention (Figure 9.18) or afterwards, giving it the highest possible easiness rating of 100 % (Figure 9.19). The mean post-test score for this skill showed the biggest gain (improving by 21 % to 74 %) with Group SV scoring significantly better than the others (Figure 9.17). The high post-test scores suggest that the lesson presentation met the learning needs of the participants and the exercises provided adequate opportunities to practice the skill of describing the direction from one place to another. It was surprising to find that the exercise scores for direction were the lowest (Figure 9.15). On closer examination of the question and answer sheets it was found that participants had ignored instructions relating to whether answers were to be derived from four, eight or sixteen points of the compass. A caution should be added that learners read questions and follow instructions more carefully.

- Position

Participants downscaled their presumption of easiness (Figure 9.19); possibly realising that accuracy when using co-ordinates was more important than previously assumed (Figure 9.18), but their scores still increased by 14 % to 52 %. Exercise scores were significantly better than pre-test scores for three of the groups suggesting that the exercises provided sufficient opportunities to practice naming places at given co-ordinates and finding the co-ordinates of named places. The pattern of better exercise scores than test scores found here is repeated and exaggerated in the following lessons. Post-test scores could perhaps be improved by using a video clip in the lesson demonstrating how to read off latitude and longitude accurately using the graticule dicing around the frame of the map extract (which is shown around the map extract in Appendix 4.1 and used around all sheets of the 1:50 000 topographic map series of South Africa.

- Bearing[1]

The presumption of easiness was high relative to the lower pre-test (Figure 9.18) and post-test scores (Figure 9.19) which had nevertheless improved, by 13 % over the pre-test score, to 44 %. Exercise scores were significantly higher than test scores in the majority of cases (Figure 9.17) suggesting that repeated contingent practice leads to improved proficiency. When participants only had one chance to measure bearing in the post-test their answers were far less accurate. A video clip may be useful to demonstrate how to (a) construct an accurate north line, (b) join the two places between which bearing is to be measured and (c) manipulate a protractor to measure the angle accurately.

- Height[2]

The easiness rating of this lesson was relatively high both before (Figure 9.18) and after the intervention (Figure 9.19). Although the post-test score for this skill was only 35 %, this represented a 16 %, albeit not statistically significant improvement on the pre-test. Post-test scores were significantly lower than exercise scores for each group. The effect of low levels of accuracy (as illustrated by the reassessed scores for Group SV in Figure 9.17 and discussed in 10.3.3) have impacted on performance and every effort must be made to improve accuracy when using the height clues on topographic maps: contour lines, trig beacons, bench marks and spot heights. The lesson uses a range of images and screen options to illustrate height including colour coded contours and hypsometric tints. It also provides an option to 'drape' the topographic map extracts over a sun-shaded digital elevation model (DEM) which greatly enhances the visualisation of relief. The lesson must be revisited to ensure that it is sequenced so that participants derive the maximum benefit from the learner support materials that are provided.

- Distance/Area

Participants' over-estimation of the easiness of this skill prior to the intervention (Figure 9.18) dropped afterwards (Figure 9.19) while their scores improved from 20 % to 37 % showing the second highest skill improvement in the programme although this was only significant for Group PI

[1] It was from this lesson onwards that Group PB no longer self-assessed their exercises; they were assessed by the researcher. Their pattern of higher exercise scores than test scores in Figure 9.17 is similar to the pattern displayed by all other groups making them a negative control to monitor the impact of self-assessment on improved performance.
[2] Alternate terminology associated with height on maps includes elevation and altitude, these terms are discussed in the glossary but the term height is preferred as a lesson title.

(Figure 9.17). It is in this lesson and the next that the effects of accuracy are most obvious from the reassessed scores of Group SV. Unlearning the old habit of using calculation shortcuts may have to be addressed in the lesson along with further opportunities to practice measuring distances and calculating areas in different units of measurement using real world scenarios to reinforce relevance (e.g. calculating farm sizes in hectares and not m² or km²). Guidance must be incorporated into the learning programme to improve learners' ability to measure distances on maps as accurately as possible (perhaps by using a demonstration video) and then to maintain a high level of accuracy in converting map distance to ground distance.

- Gradient[3]

Low to start with, the assumption of easiness showed a decline between the pre-intervention assessment (Figure 9.18) and the post-intervention assessment (Figure 9.19). From a mean pre-test score of 3 % the mean post-test score for this task increased to only 9 %. Group SS showed a significant improvement (perhaps because no member of the group had scored a single point for this task on the pre-test) but even their post-test score was still far from acceptable. Exercise scores were significantly higher than test scores for all groups. The effects of low levels of accuracy had a double impact on the score for this task because if participants miscalculated either the difference in height or distance between the top and bottom of the slope in the post-test, the answer to the gradient calculation (which is expressed as a ratio between the two) would be incorrect. As illustrated in Figure 9.17, the flexible marking memorandum used to remark the pre- and post-test scores for Group SV had a statistically significant impact on the scores for all three tasks – height, distance and gradient. Improvements, already suggested, to the lessons on height and distance may also improve performance in gradient calculation. A more practical demonstration of how the two measurements are related is perhaps required and further explanation of why gradient is important could be added to the lesson.

- Profiles

This skill received the lowest easiness assessment prior to the intervention (Figure 9.18). Although the mean score improved by 9 % to 30 %, no participant found the profile lesson easy (Figure 9.19). The lower than average exercise scores for Group PI are discussed in 10.3.3. On this task they have attained a significantly better post-test score than the other groups (Figure 9.17) suggesting that they have reaped the benefit of honest effort by working through the instructions carefully and then working accurately. The high variability of the data presented in the profiles graph in Figure 9.17 is

[3] The exceptionally high exercise score for Group PB is suspect because three boys handed in the same exercise on gradient and all three had admitted to cheating. Because the group's post test scores were lower than their pre-test scores, it is doubtful whether they had attempted to work out the answers to the gradient exercise.

due to the small number of learners who managed to get all the way through the programme; Group PB did not even attempt profiles. Because drawing a profile is largely a manual task, a practical demonstration on video should be added to the lesson on this skill. This should include preparing the profile framework, gathering height data, manually plotting this data and then accurately drawing in the profile between the plotted data points.

10.5.2 Improvements to programme components

The two components that were rated least useful (Figure 9.24) were the voice-overs and the movie clips. Different responses to the inclusion of sound in the programme are illustrated in Figure 9.25. Learners '... are different, and it is good practice to recognise and accommodate individual differences. It is also good practice to present information in a variety of ways through more than one modality' (Snider, 1990: 53). As the technology is available to make sound an option to be turned on or off, special care should be taken to ensure that important text sections have voice-overs and that current voice-over sections also have text displayed in order to suit those who have a disposition towards either visual or auditory learning styles (Gardner, 1985; Leaf, 2002).

While movie clips were rated as the least useful component, this may well have been caused by technical difficulties which can be overcome by including the appropriate software for downloading the video clips with the programme installation setup. Many recommendations for improvements to the lessons involve the addition of video footage to demonstrate manual skills.

10.6 SUPPORT FOR GEOGRAPHY TEACHERS

The analysis of geography practical examination scores (Figure 1.4) confirmed that there is a widespread spatial competence problem among school leavers in South Africa. One solution to the problem lies in providing adequate resources to counter the lack of facilities reported by teachers (Table 6.1). Providing adequate stocks of various maps, teaching notes and handbooks with exercises (and answers) in hard copy is very expensive. While some hard copy resources are obviously required, these can be supplemented by a great variety of digital spatial information products and animated illustrative materials using GIS. Once such learning materials for Geography are available in digital format, then pressure can be applied by teachers of Geography to ensure that their subject also receives the benefits of the ICT facilities that are progressively being provided to more and more schools (Bialobrzeska and Cohen, 2005; Khanya, 2005; Matandela, 2008). Ways of collaborating with Mathematics teachers who are currently the major beneficiaries of these developments must be investigated.

Although the NCS for Geography (DoE, 2003) makes provision for enhancing spatial competence in the future (as discussed in Chapter Two), there is little guidance provided for progression (Beets and Le Grange, 2005). This is a particular problem when teaching map skills. Evidence provided by the errors made by teachers (Figure 6.1) in the LTSM collaborative writing attempt suggest that some teachers were unfamiliar with the correct terminology, with the levels of accuracy required and with the appropriate sequencing of skills in the map reading-analysis-interpretation hierarchy. Mathematics competence, shown to impact positively on map analysis skills (Figure 4.3) was seriously compromised by apartheid education policies which limited the scope and depth of subjects offered to people previously legislated as Black (Appendix 1.1). Because of its complexity, the language used by geography teachers is particularly important (Butt, 2002), especially when dealing with spatial concepts, techniques and skills. However, the majority of South African teachers are not teaching in the home language of their learners (as evidenced in Table 3.8) or their own home language; a matter requiring serious attention in the attempt to improve spatial competence. The teaching methods required for spatial skills development are more specialised than methods used to teach Geography content (Naish, 1982; Lambert, 2002; Wiegand, 2006b).

Offering professional training to large numbers of new and in-service teachers is clearly required but is costly (in terms of both time and money). Used in an appropriate setting, a computer-based self-instruction learning programme such as MapTrix Geomatica can meet many of the resource and training needs of geography teachers that were identified when conducting the *MapTrix* survey and as reported in Chapters Three and Six.

10.7 CONCLUSION

In this concluding essay the questions asked in the introduction to this chapter are answered. Yes, MapTrix Geomatica works. Yes, self-instruction works - when mediated by the teacher. Yes, GIS works as a delivery mechanism for map analysis learning materials (and much more). Yes, there are ways in which the programme can be improved. Apart from the possible application of the computer-assisted self-instruction methodology to other school subjects and probably to other topics in Geography, the most pressing wider application for the findings is currently in teacher training.

The key findings of this investigation, which indicate most clearly that the self-instruction method can be used to improve spatial analysis skills, are: the statistically significant improvement of 13.4 % in map analysis mean scores under trial conditions (Table 9.2), affirmation by 96 % of trial participants that the programme had met its objective of improving their map analysis skills and the favourable attitude to MapTrix Geomatica evidenced by 81.8 % of participants (Figure 9.30). Part of the success of the programme is due to the thorough preparation of the trial candidates. Where teachers could not confirm that participants were already proficient map readers and competent computer users, the MapTrix Digital Game proved effective in ensuring that all participants started the trials on a level playing field.

According to the definition of spatial competence approved by two focus groups (Box 5.2), map analysis is only one skill in the spectrum of abilities required for effective spatial decision making, and topographic maps only one source of spatial information. The results of this trial suggest that, provided appropriate computer facilities are available, learners of any gender or age can benefit from using the self-instruction method to improve map analysis as long as they have a positive attitude and apply themselves diligently. Further, the results suggest that the same design and methodology could be used to develop a learning programme for the analysis of other sources of spatial information. Translation of some components of the programme may be required for non-English speakers. Those taking subjects that support Geography such as Science and Mathematics would undoubtedly make the fastest progress.

While the programme was designed with the intention that learners should be able to teach themselves relevant map analysis skills, it remains the responsibility of the teacher to establish and manage the learning environment. For this reason it is strongly recommended that teachers be offered training in the use of the programme prior to its implementation with learners. In order to provide teachers with evidence of learning for the purpose of monitoring learners' progress, a record of all answers and their assessment by learners must be kept. Teachers should observe learners closely to ensure that they have sufficient resources and opportunity to practice the manipulation of measuring instruments and that they work as carefully as possible to eliminate careless errors.

As with skill acquisition in general, sufficient time must be made available for learners to use all lesson elements and practice new skills. Using MapTrix Geomatica, they should complete both exercises per lesson if their scores do not indicate mastery after one exercise. Teachers must be alert to learners' progress so that they can offer individualised tuition if necessary. No computer assisted learning programme can ever be a substitute for a highly competent map user when training a novice. However, in a situation where the teacher may not have had sufficient map use training or where large numbers of learners simultaneously need training in spatial analysis skills or where individual learners need to improve their skills in order to participate fully in a classroom where others are highly competent, in such cases the introduction of a self-instruction programme for the analysis of spatial information would appear to be especially effective.

GIS is not just another teaching resource that can be added to the geography classroom like a globe, wall map, overhead projector, personal computer linked to digital projector or interactive white board. The advancement of spatial thinking and the development of the geo-spatial technologies that have both inspired and stimulated it (NRC, 2006), have the potential to completely revolutionise teaching in, for and about the WORLD (see Figure 2.1). Programmes such as AGSSS (Bednarz and Bednarz, 2008) can be useful in setting high standards for future geography teacher training in first world settings. While these lofty goals may be attained by all in time, the current needs of learners (and teachers) in South Africa and other countries that have reached a similar level of IT, ICT and GIS integration, can be addressed in incremental steps using just those aspects of GIS technology suited to accomplishing those small steps.

The assumptions about GIS, upon which the main hypothesis rests, are valid (see Chapter Seven - 7.1.3). Their positive attitude towards GIS confirms that learners had the opportunity to visualise and interrogate various sources of spatial data in an interactive, novel and stimulating learning environment. By introducing learners to the potential of GIS in very small incremental steps, starting with topographic map study, which has long been a requirement in Geography, the majority indicated that they wanted to know more about GIS. This would include more extensive use of GIS for map interpretation and later map generation. Problems with accuracy and efficiency when executing map analysis tasks manually were still evident. Improvements in this area, using a limited selection of GIS tools, were small but significant.

The programme can immediately be improved by the eradication of errors and omissions as listed in the product report in Appendix 9.1. Proposed improvements to the programme, especially to the mathematics sub-lessons, should increase efficacy. Although mathematical skills were identified as important for the improvement of map analysis skills, it seems that insufficient attention was paid to the issue of accuracy. Mathematical terminology was included in the glossary but there is evidence that these terms and the mathematical sub-lessons were not consulted by all participants (Figure 9.24). A means to enhance the mathematics sub-lessons must be found to emphasise the importance of accuracy. Ways must be found to demonstrate the effects of inaccuracy so that learners understand why careful measurement is important. The addition of video clips to demonstrate the manipulation of measurement instruments is recommended.

Future plans include the application of the findings of this investigation to the upgrading of the existing prototype and to the development of the rest of the lessons already planned for the full map analysis section of the MapTrix Geomatica programme (Table 7.1). Once a wider range of map analysis lessons has been developed based on 36 of the 52 *MapTrix* map extracts then the balance of 16 map extracts will be used to develop map interpretation skills using the GIS tools to illustrate more complex spatial data analysis, manipulation and product generation. It is anticipated that generic activities will be developed for which local spatial data can be imported and learners will be encouraged to undertake GIS enabled investigations with local relevance in their home areas (Page *et al*., 2001; Fitzpatrick and Maguire, 2001; Maguire, 2006; Wiegand, 2006a and b).

Map study, including extracting, analysing and comparing information from maps is now prescribed at GET level (DoE, 2002a), topographic maps are specifically mentioned as one of the types of maps to be used and strong emphasis is placed on investigating local issues using fieldwork. Policies are thus in place for improving the spatial competence of learners entering the FET band (DoE, 2003). The challenge is that the number of practising geography teachers in South Africa is declining rapidly (Fairhurst *et al.*, 2003). The Social Sciences Learning Area is, more often than not, taught by history teachers who are unlikely to have had specific map use training. Indeed, in some areas, where there is a high percentage of under-resourced schools, Geography as a school subject at FET level is under threat precisely *because* of the decision to include GIS in the geography curriculum (pers. comm. S. Neuhoff, provincial geography examiner). It is ironic, just when the importance of spatial thinking is being acknowledged and the value of GIS for enabling such thinking clearly understood (NRC, 2006), that the teachers who are required to nurture this competence are being attracted away from the teaching profession and joining new geography graduates in the wide range of positions opening up in municipal and provincial administrations, environmental agencies, utility companies and in the geospatial and related services industries.

Although the scores for the Western Cape were not the lowest in the country, there is clearly a connection between poor geography practical examination results (Figure 1.4) and low levels of competence among teachers in an activity that required the setting and answering of map analysis questions (Table 6.4). The efficacy of MapTrix Geomatica has now been demonstrated. It is strongly recommended, once the final programme has been developed incorporating the findings of this investigation, that it be used as the basis of teacher training in situations where both spatial competence must be improved and GIS must be introduced in keeping with the requirements of the NCS for Geography (DoE, 2003and following). The programme has applications at two levels in the teacher training environment: enhancing the training of the few new teachers that are entering the profession and upgrading the skills of the older, in-service teachers denied adequate schooling and training under discriminatory apartheid education policies.

To expand the metaphor credited to Fitzpatrick of ESRI where he compares some teachers use of GIS with '...using a Ferrari for commuter traffic' (Alibrandi and Baker, 2008: 17) - would a novice driver, who had no road sense, no way-finding ability and no driving skills be allowed into a Ferrari in the first place, whether in the commuter traffic or on the open road? Would the said novice not be safer on a bicycle, learning the rules of the road in the relative safety and familiarity of their own neighbourhood? This is what MapTrix Geomatica, the envisaged self-instruction programme for analysing spatial information, is offering. While encouraging the aspiration to drive the Ferrari one day, the proposal is that some, quite limited, vehicle features may be used to teach the basics of way finding and driving techniques first. Subsequently, the open road will offer limitless possibilities for spatial skills enhancement.

REFERENCES

A

Adey, P. and Shayer, M., 1994: Really Raising Standards, Routledge, London.

Alexander, K. and Blanchard, D. (eds), 1985: *Educational Software*, Microelectronics and Education Programme, Tecmedia, Loughborough.

Alexander, L. A., 2000: Intimate Cartographies, Duckworth Literary Entertainments, London.

Alibrandi, M. and Baker, T., 2008: A social history of GIS in education, 1985-2007, in A. J. Milson and M. Alibrandi (eds), *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, Information Age Publishing, Charlotte, NC, 3-37.

Andersland, S., 2006: GIS in Norwegian lower and upper secondary school, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, Brisbane, 39-42.

Anderson, J. M., 1996: I love maps ... but is that a road map or a weather map?, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, (67-80).

Anderson, J. M., 2003: Cartography and children – at the dawn of its development?, paper presented at the 21st International Cartographic Association Conference, Durban, South Africa.

Anderson, J., Carrière, J., Pitre, P. and Le Sann, J., 2005: The development of an internet school atlas – a case study: the Atlas of Quebec, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 131-136.

Anderson, J. M., Carter, J. R., Ormeling, F. and Kanakubo, T., 1996: Foreword in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan (i-iii).

Anderson, P. S. and Blanco do Valle, K., 2003: Low-cost solution from Mozambique for appropriate large-scale mapping for urban planning with GIS interface, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Anderson, P. S. and Innes, L. M., 2003: Globe Maps: Novelty or cartographic education necessity?, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Anderson, T. P., 1997: Using models of instruction in C. R. Dills and A. Romiszowski (eds) *Instructional Development Paradigms*, Educational Technology Publications, New Jersey.

Annegarn H., 2008: Sustainable intellectual communities: Best practice in emerging countries in high technology partnerships, paper presented at the Global Dialogues on Emerging Science and Technology (GDEST) Conference, 17-19 March, Cape Town.

Ashwell, A., 2007: Youth, GIS and urban nature, report tabled at a Geography Teacher's Seminar during GIS Week at the University of the Western Cape, Cape Town.

Advisory Unit for Microtechnology in Education (AUME), 1990: National Curriculum Software Scheme: Geographical Information System for Schools, press release 1:NCET/DES 2pages, (referenced in Green, 2001).

Avian Demography Unit, University of Cape Town, 2001: Article from Africa in *GEOEurope*, 10(6), 16.

B

Bailey, P. and Fox, P., 1996: Teaching and learning with maps in P. Bailey and P. Fox (eds), *Geography Teachers' Handbook*, Geographical Association, Sheffield 109 – 115.

Baker, T. R. and Bednarz, S. W., 2003: Lessons learned from reviewing research in GIS education, Journal of Geography, 102, 243-254.

Balchin, W. G. V., 1985: Graphicacy comes of age, *Teaching Geography*, October, 8-9.

Ballantyne, R. R., 1987a: *Change in secondary school geography education: Teacher attitudes and practice*, Department of Environmental and Geographical Science, Report 60, University of Cape Town.

Ballantyne, R.R., 1987b: Geography's position in the secondary school curriculum - pupil enrolment trends, *South African Geographical Journal*, 70, 72-78.

Ballantyne, R.R., 1999: An analysis of geography teacher educators' perceptions of Curriculum 2005, in *South African Geographical Journal*, 81(2), 75-79.

Bartlett, F. C., 1932: *Remembering*, Cambridge University Press, Cambridge.

Beard, R. M., 1969: *Outline of Piaget's Developmental Psychology*, Student's Library of Education, Routledge, London.

Bednarz, S. W., 2000: Problem-based learning in R. Audet and G. Ludwig (eds) *GIS in Schools*, ESRI Press, Redlands California, 89-101.

Bednarz, S. W. and Bednarz, R. S., 2008: Spatial thinking: the key to success in using geospatial technologies in the Social Sciences classroom, in A. J. Milson and M. Alibrandi (eds), *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, Information Age Publishing, Charlotte, NC, 249-270.

Bednarz, S. W., Bednarz, R. S. and Petersen, J. F., 2006: Intercultural dialogue on educational approaches to sustainable development: United States, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 63-67.

Beets, P. and Le Grange, L., 2005: Continuity and progression: the Achilles' heel of the National Curriculum Statement for Geography, in *South African Journal of Education*, 25(3), 190-197.

Beets, P., Hanekom, F., Innes, L., Kotzé, J. C., Samaai, G., Smit, T. and Swanevelder, C. J., 2005a: *OBE for FET Senior Geography Grade 10 Learner's Book*, Nasou Via Afrika, Cape Town.

Beets, P., Hanekom, F., Innes, L., Kotzé, J. C., Samaai, G., Smit, T. and Swanevelder, C. J., 2005b: *OBE for FET Senior Geography Grade 10 Teacher's Guide*, Nasou Via Afrika, Cape Town.

Beets, P., Dyssel, M., Hanekom, F., Innes, L., Kotzé, J. C., Najjaar, K., Smit, T. and Swanevelder, C. J., 2006a: *OBE for FET Senior Geography Grade 11 Learner's Book*, Nasou Via Afrika, Cape Town.

Beets, P., Dyssel, M., Hanekom, F., Innes, L., Kotzé, J. C., Najjaar, K., Smit, T. and Swanevelder, C. J., 2006b: *OBE for FET Senior Geography Grade 11 Teacher's Guide*, Nasou Via Afrika, Cape Town.

Beets, P., Hanekom, F., Innes, L., Kotzé, J. C., Najjaar, K., Samaai, G., Smit, T. Swanevelder, C. J. and Taylor, S., 2007a: *OBE for FET Senior Geography Grade 12 Learner's Book*, Nasou Via Afrika, Cape Town.

Beets, P., Hanekom, F., Innes, L., Kotzé, J. C., Najjaar, K., Samaai, G., Smit, T. Swanevelder, C. J. and Taylor, S., 2007b: *OBE for FET Senior Geography Grade 12 Teacher's Guide*, Nasou Via Afrika, Cape Town.

Beets, P., Hanekom, F., Innes, L., Kotzé, J. C., Najjaar, K., Samaai, G. and Swanevelder, C. J., 2008: *OBE for FET Senior Geography Grade 10 Learner's Book*, Nasou Via Afrika, Cape Town.

Béneker, T., Sanders, R., Tani, S., Taylor, L. and Van der Vaart, R., 2006: Success factors for innovation in geographical education, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, Brisbane, 74.

Benimmas, A., 2006: Teaching geographic reasoning, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 75-79.

Bennetts, T., 2002: Continuity and progression, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London.

Bereiter, C. and Scardamalia, M., 2007: Toward research-based innovation, in pre-publication release of *Alternate Models of Learning (AML)*, Centre for Educational Research and Innovation (CERI), Directorate for Education, reference no.: EDU/CERI/CD/RD(2007)3.

Berry, B., Davidson, J. and Thormeyer, T., 2001: Geographers in the gamadoelas: groping with graphicacy, paper presented at SSAG Conference, Goudini, 2001.

Bialobrzeska, M. and Cohen, S., 2005: *Managing ICTs in South African Schools: A Guide for School Principles*, South African Institute of Development Education (downloaded from www.saide.org.za).

Biilmann, O., 1995: GIS in general education: a didactic framework, in I. T. Bjorke (ed.), *Proceedings ScanGIS '95*, Norwegian Institute of Technology, University of Technology, Trondheim, 162-176.

Biilmann, O., 2001: GIS and remote sensing in primary and secondary education: Rationale, strategies and didactics, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 137 – 144.

Bill, R., 2001: GIS education in Germany: A survey and some comments, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 175 – 183.

Binns, T., 1999: Is Geography going places?, in *South African Geographical Journal*, 81(2), 69-74.

Blackbeard, A. D., 1992: Mapwork Made Easy, Heinemann-Centaur, Pietermaritzburg.

Bless, C. and Higson-Smith, C., 1995: Fundamentals of Social Research Methods: An African Perspective, Juta, Cape Town.

Block, E. and Rollnick, M., 2003: 'Words used are understandable; the way the information is phrased is impossible to understand' in the Proceedings of the 11th Annual Conference of the South African Association for Research in Mathematics and Science Education (SAARMSTE), 11 – 15 January 2003, Waterford Kamhlaba, University of Swaziland.

Boardman, D., 1983: *Graphicacy and Geography Teaching*, Croom Helm, London.

Boardman, D., 1985: Graphicacy and the slow learner, in G. Corney and E. Rawling (eds), *Teaching Slow Learners Through Geography*, The Geographical Association, Sheffield.

Boardman, D., (ed.) 1986: *Handbook for Geography Teachers*, The Geographical Association, Sheffield.

Boardman, D., 1996: Learning with Ordnance Survey maps, in P. Bailey and P. Fox (eds), *Geography Teachers' Handbook*, Geographical Association, Sheffield, 117 – 123.

Boehn, D. and Henry, R., 2006: Intercultural dialogue on educational approaches to sustainable development: Germany, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 80-84.

Boulding, K. E., 1965: *The Image*, Ann Arbor, University of Michigan Press. (Referenced in Downs and Stea *Image and Environment.)*

Boulding, K. E., 1973: Foreword in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, vii-ix.

Brooke, G., 2001: Not just visualization – simulation, in *Geo Informatics*, 4(6), 6-9.

Brown, M. J., 2001: Geographical Information Systems: An introduction for students, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 94 – 113.

Brown, A. L. and Palincsar, A. S., 1982: Introducing strategic learning from text by means of informed, self-control training, in *Learning and Learning Disabilities*, 2(1), 1-17.

Bunch, R., Nelson, E., Lloyd, R. E., Kane, M. and Tricot, T., 2008: Instructional Geographic Information Science: a multidisciplinary framework for geospatial technologies in education, in A. J. Milson and M. Alibrandi (eds), *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, Information Age Publishing, Charlotte, NC, 227-245.

Bunting, B., 1986: *The Rise of the South African Reich*, IDAF, London (reference in Wesso and Parnell, 1992).

Burton, M. StJ. W., 1986: Graphicacy and the third dimension: an investigation into the problem of poor performance in relief mapwork in South African schools, unpublished M.Ed. thesis, Rhodes University.
Burton, M.StJ.W., 1989a: Class encounters with the third dimension, *South African Geographer*, 16(1/2), 130-138.
Burton, M.StJ.W., 1989b: Three-dimensional graphicacy and contour work, paper presented at the Conference of the Society for Geography, Pretoria.
Burton, M.StJ.W., 1990: Examining mapwork in standard 10: an update, paper tabled at the annual meeting of Moderators and Examiners for Geography, 24 August 1990, Bloemfontein, South Africa.
Burton, M.StJ.W., 1992: Are our right brain graphicacy skills in South African geography about to experience major 'surgery'?, *Geogram*, South African Geographical Society Schools Newsletter, 5.
Burton, M. and Pitt, I., 1993: South African Mapcraft, Shuter and Shooter, Pietermaritzburg.
Butt, G., 2002: Language and learning in Geography, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 200-211.
Buzan, T., 1991: *Use Both Sides of Your Brain*, Plume, New York

C

Cadoux-Hudson, J. and Heywood, D. I., (eds) 1993: *The Yearbook of the Association for Geographic Education 1992-1993*, Taylor & Francis, London.
Campbell, J., 1984: *Introductory Cartography*, Prentice-Hall, New Jersey.
Campbell, N., 1989: The spreadsheet as a low cost Geographical Information System, paper presented at a Workshop on New Technology and Spatial Information Systems, University of Nottingham, January 1989, (16 pages).
Campbell, N., 1990: The spreadsheet and the political economy of GIS, paper presented at University of Leicester, (referred to in Green, 2001b).
Caquard, S., Pulsifer, P. and Taylor, D. R. F., 2005: Multiple ways of learning about Antarctica with cybercartography, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 110.
Carolissen, M., McPherson, E. and Kleyn-Magolie, B., 2006: Perceptions and challenges facing educators with the introduction of GIS into the school curriculum: Western Cape, South Africa, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 103.
Cartwright, W., 2005: Delivering education with contemporary tools, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 170-176.
Casti, E., 2005: Web GIS semiosis: building a plural place, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 189-194.
Castner, H.W., 1979: Viewing time and experience as factors in map design research, *The Canadian Cartographer*, 16(2), 145-158.
Castner, H. W., 2002a: Do numerical and cartographic analysis need to be demystified? in *Cartographia para Escolares no Brasil e no mundo*, Belo Horizonte: CD-Rom, 197-200.
Castner, H. W., 2002b: Are there shared mathematical concepts in geographic education? in *Cartographia para Escolares no Brasil e no mundo*, Belo Horizonte: CD-Rom, 197-200.
Catling, S. J., 1978: The child's spatial conception and geographic education, *Journal of Geography*, 77(1), 24-28.

Centre for GIS and Remote Sensing of the National University of Rwanda (CGIS-NUR), 2009: Newsletter of the ArcGIS in Secondary Schools Project, Rwanda, http://www.cgisnur.org

Chaloner, M., 1992: GIS in European schools, emulation, education, Geography and GIS, in *Mapping Awareness and GIS in Europe*, 6(6), 30-31.

Chamberlain, C. S., 1995: A foundation course in Geography: Transforming teaching and learning – the Wits experience, paper presented at the First International Geography Conference of the Society for South African Geographers**,** Pietermaritzburg, South Africa.

Chen, C-M. J. and Li, H-Y, 2006: Problem-based learning in high school Geography: a case study from the Tou-cheng Beach in northeast Taiwan, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 125-128.

Chief Directorate: Surveys and Mapping (CDSM), 1997a: *MapAware Map Symbols*, video produced for the MapAware Project by Edumedia, Cape Town (from audio slide show produced by Linkin).

Chief Directorate: Surveys and Mapping (CDSM), 1997b: Gordon's Bay Training Map based on sheet 3418BB Somerset West, 1:50 000 South African Topographic Map Series, produced for the MapAware Project, Cape Town.

Chief Directorate: Surveys and Mapping (CDSM), 2000: *Reading a Topographic Map with MapTrix* (video produced by Edumedia), Cape Town, South Africa.

Chief Directorate: Surveys and Mapping (CDSM), 2003: Table Bay and Hout Bay, amalgamation of sheets 3318CD and 3418AB, 1:50 000 South African Topographic Map Series, for University of Cape Town.

Chisholm, L., 1984: Redefining skills: Black education in South Africa in the 1980's in P. Kallaway (ed) *Apartheid and Education*, Ravan, Johannesburg, 387-409.

Chisholm, L., Volmink, J., Ndhlovu, T., Potenza, E., Mahomed, H., Muller, J., Lubisi, C., Vinjevold, P., Ngozi, L., Malan, B. and Mphahlele, L., 2000: *A South African curriculum for the twenty first century: Report of the review committee on Curriculum 2005*, Department of National Education, Pretoria.

Chisholm, L., 2005: The making of South Africa's National Curriculum Statement, in *Journal of Curriculum Studies*, 37(2), 193-208.

Christaller, 1972: How I discovered the theory of central places: A report about the origin of central places in P. W. English and R. C. Mayfield (eds), *Man, Space and Environment*, Oxford University Press, New York, 601-610.

Christopher, A. J., 2003: Land: a recurring theme in South African Historical Geography, in *South African Geographical Journal*, 85(2), 115-124.

Ciolli, M., Righetti, M., Sboarina, C., Tattoni, C., Vitti, A., Zatelli, P and Bertola, P., 2008: How open source GIS and related tools can help an African project and projects help to develop new tools: The case of Rwanda and the new GRASS-Epanet Interface, paper presented at 2008 Free and Open Source Software for Geospatial (FOSS4G) Conference (incorporating the GISSA 2008 Conference,) 29 September-3 October 2008, Cape Town.

Clark, E. A. G., 1989: Geography as a school subject in South Africa, *South African Geographical Journal*, 71(1), 46-55.

Clarke, D. G., 1996: Learning to read maps, *Journal* (House Journal of the Department of Land Affairs), 4/96, 5.

Clarke, D. G., 1997: Mapping for the reconstruction of South Africa, in D. Rhind (ed.), *Framework for the World*, GeoInformation International, Cambridge, 48-62.

Clarke, D. G., 1998: Free maps for secondary schools, *Landinfo*, 5(1), 5

Clarke, D. G., 2003: Are you functionally map literate? *Proceedings of the 21st International Cartographic Conference* (ICC), Durban, South Africa.

Clarke, D. G., 2008: Status of GIS in Africa, *GIS Development*, 12(1), 40-43.

Coggins, P. C., 1990: Horses for courses: education in GIS, paper presented at Mapping Awareness Conference 1990, Blenheim, London, 19.1-19.5.

Cohen, R., 1985: What's so special about spatial cognition?, in R. Cohen (ed.), *The Development of Spatial Cognition*, Lawrence Earlbaum Associates, Hillsdale, New Jersey, 1-11.

Cohen, L. and Manion, L. 1985 (2nd ed.): *Research Methods in Education*, Croom Helm, London.

Colley, A. and Comber, C., 2003: Age and gender differences in computer use and attitudes among secondary school students: what has changed? in *Educational Research*, 45(2), 155-165.

Conacher, R. C., 1993: Challenges in teacher education and the teaching of Geography, paper presented at a symposium (11 August 1993*), A Future for Geography in Education*, University of Pretoria.

Cooper, A. K. and Coetzee, S, 2008: The South African address standard and initiatives towards an international address standard, paper presented at 2008 Free and Open Source Software for Geospatial (FOSS4G) Conference (incorporating the GISSA 2008 Conference) in 29 September – 3 October 2008, Cape Town.

Cowie, T., 1994: The relationship between standard 10 higher grade geography and the first year geography undergraduate course at university: an examination, *Geogram*, South African Geographical Society Schools Newsletter, 10, 3-7.

Craigie, D., 2008: GIS and integrated water resource management, in *PositionIT*, GISSA Journal, Mar/Apr 2008, 34-39.

D

Davies, D. H., 1988: School geography: a university perspective, *South African Geographer*, 15(1/2), 116-126.

Davies, L.S., 1983: An investigation into the problems in the use of topographic survey maps among secondary school pupils in Zimbabwe, unpublished M.Phil. Thesis, University of Zimbabwe.

Davis, R. H., 1984: The administration and financing of African education in South Africa 1910-1953 in P. Kalaway (ed) *Apartheid and Education*, Ravan, Johannesburg, 127-138.

de Greef, G., 2001: Terrain and land cover mapping for Africa's mobile telephony market, *GEOEurope*, 10(6), 44-45

de Sousa, L. O., Richter, B. W. and Nel, C., 2006: The integration of digital video discs (DVD's) and multimedia in training pre-service geography teachers, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 140-145.

Department of Education and Culture, 1992: *Working Document for Geography, Higher Grade, Standards 8, 9 and 10*, dates of implementation 1993, 1994, 1995, House of Assembly, Cape Town.

Department of Education and Training (DET), 1992: *1992 Annual Report*, Government Printer, Pretoria.

Department of Education and Training (DET), 1993: *1993 Annual Report*, Government Printer, Pretoria.

Department of Education (DoE), 2002a: *Revised National Curriculum Statement Grades R-9 (Schools) Policy*, Department of Education, Pretoria.

Department of Education (DoE), 2002b: *Phasing in OBE into the FET Band: Implementation Strategies (2004 - 2006),* Department of Education, Pretoria.

Department of Education (DoE), 2003: *National Curriculum Statement Grades 10-12 (General) Geography,* Department of Education, Pretoria.

Department of Education (DoE), 2004: *Learning Outcomes and Assessment Standards Grades 10-12 (General)* Department of Education, Pretoria.

Department of Education (DoE), 2005: *The National Senior Certificate: A Qualification at Level 4 on the National Qualifications Framework (NQF)*, Department of Education, Pretoria.
Department of Education (DoE), 2007: *National Curriculum Statement Assessment Guidelines for General Education and Training (Intermediate and Senior Phases) Social Sciences*, Department of Education, Pretoria.
Department of Education (DoE), 2008a: *National Curriculum Statement Grades 10-12 (General), Learning Programme Guidelines: Geography*, Department of Education, Pretoria.
Department of Education (DoE), 2008b: *National Curriculum Statement Grades 10-12 (General), Subject Assessment Guidelines*, Department of Education, Pretoria.
Department of Education (DoE) and Department of Labour (DoL), 2002: *Report of the Study Team on the Implementation of the National Qualifications Framework*, The Government Printing Works, Pretoria.
Department of Land Affairs (DLA), 1999: *Annual Report*, Pretoria.
Department of Land Affairs (DLA), 2000: *The Chief Directorate: Surveys and Mapping, 80 Years of Surveying and Mapping South Africa*, Department of Land Affairs Media Production Unit, Pretoria.
Donert, K., 2006: The use of ICT and eLearning in Geography: HERODOT perspectives in European higher education, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications,146-154.
Downs, R. M., 1985: The representation of space: Its development in children and cartography, in R. Cohen (ed.), *The Development of Spatial Cognition*, Lawrence Erlbaum Associates, Hillsdale, page 323 – 345.
Downs, R. M. and Liben, L. S., 1991: The development of expertise in geography: A cognitive-developmental approach to geographic education, *Annals of the Association of American Geographers*, 81(2), 304-327.
Downs, R.M. and Stea, D., 1973a: Cognitive maps and spatial behaviour: Process and products, in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 8-26.
Downs, R.M. and Stea, D., 1973b: Cognitive representations, in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 79-86.
Downs, R.M. and Stea, D., 1973c: Development of spatial cognition, in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 221-225.
Downs, R.M., Liben, L.S. and Daggs, D.G., 1988: On education and geographers: The role of cognitive developmental theory in geographic education, *Annals of the Association of American Geographers*, 78(4), 680-700.
Dresden, M. and Trevedi, D. M., 2008: The use of OpenLayers for the demonstration and web visualization of environmental applications, paper presented in the technical session of the Free and Open Source Software for Geospatial (FOSS4G) Conference (incorporating the GISSA 2008 Conference) in October in Cape Town, South Africa.
du Toit, G. F. and du Toit, E. R. 2004: Understanding outcomes-based education (OBE) in J. G. Maree and W. J. Fraser, *Outcomes-based Assessment*, Heineman, Sandown, 1-27.

E

Earle, J. and Keats, G., 1996: A case for Geography in the curriculum framework for general and further education and training, a paper presented at the Learning Areas Committees meeting at Technikon RSA, 16-20 September, Johannesburg.
Earle, J. and Bowerman, P, 2007: *Focus on map skills*, Maskew Miller Longman, Cape Town.
Eastman, J. R. 1985: Cognitive models and cartographic design research, *Cartographic Journal*, 22(2), 95-101.
Ebdon, D., 1985: *Statistics in Geography*, Basil Blackwell. Oxford.
Eiselen, L., 1991: *Zap Map* (video series), Kagiso, Cape Town.

Ekiss, G. O. and Trapido-Lurie, B., 2006: Stars squiggles and humps: Arizona Geographic Alliance's adventures into children's cartography, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 155-159.

Engel, B. P. and van Geems, B., 2000: Bringing map literacy to the nation, *LANDinfo*, 7(3), 10.

Engel, B. P., 2002: No land reform without spatial information, paper presented at the Regional Conference of the International Geographical Union, Durban, South Africa.

Engel, B. P., 2003: The application of spatial information for land reform in South Africa, paper presented at 21st International Cartographic Conference (ICC), Durban, South Africa.

English, K. Z. and Feaster, L. S., 2003: *Community Geography: GIS in Action*, ESRI Press, Redlands, California.

F

Fairburn, D., 2005: Mapping the World: an educational reference work for high school students, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 143-148.

Fairgrieve, J., 1926: *Geography in School*, University of London Press, London.

Fairhurst, U. J., 1993: The potential of geography as a school subject: anything changed? ... anything to change? paper presented at a symposium (11 August 1993*), A Future for Geography in Education*, University of Pretoria.

Fairhurst, U. J., 2002: South African Qualifications Authority (SAQA) and the implications it holds for Geography: a hornet's nest?, paper presented at the Regional Conference of the International Geographical Union, Durban, South Africa.

Fairhurst, U. J., Davies, R. J., Fox, R. C., Goldschagg, P., Ramutsindela, M., Bob, U. and Khosa, M. M., 2003: Geography: the state of the discipline in South Africa (2000-2001), *The South African Geographical Journal*, 85(2), 81-89.

Faller, F., 2004: Matric results: what do they really mean?, *Arena*, University of the Witwatersrand, Johannesburg, 11(33), 8-9.

Feldmann, H., 1996: Fun and games in learning how to read maps, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan (112-119).

Ferreira, M. M., 2006: Sustainable urban development: The role of citizens, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 160-165.

Feuerstein, R., 1980: *Instrumental Enrichment: An Intervention Program for Cognitive Modifiability*, University Park Press, Baltimore.

Feuerstein, R., Rand, Y. and Rynders, J. E., 1988: *Don't Accept me As I Am: Helping "Retarded" People to Excel*, Plenum, New York.

Fitzpatrick, C., 1993: ArcSchool Reader makes debut, in *Arc News*, Summer 1993, page 38.

Fitzpatrick, C and Maguire, D. J., 2001: GIS in schools: Infrastructure, methodology and role in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 62 – 72.

Flemming, G., 2008: FOSS4G education outreach at Bishops, in *PositionIT*, GISSA Journal, Nov/Dec 2008, 12.

Fodor, J. A., 1980: Fixation of belief and concept acquisition, in M. Piatelli-Palminari (ed.) *Language and Learning: The Debate between Chomsky and Piaget*, Harvard Press, Cambridge MA., page 143 – 149.

Forster, M., McConnell, T. and Schilling, M., 2007: Introducing GIS to K12 Education in Rwanda, paper presented at ESRI User Conference, 2007.

Fox, R. and van der Stok, A., 1999: The more things change, the more they remain the same: Geographical dimensions of educational change in 57 Eastern Cape schools 1988-1998, paper presented at the 3rd Biennial International Conference of the Society of South African Geographers, Windhoek, Namibia.

Francis, H., 1997: The research process in N. Graves and V. Varma (eds), *Working for a Doctorate*, Routledge, London, 18-34.

Freeman, D., 2006: Creating geographical worlds: an investigation into the construction of school Geography, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 172-176.

Freeman, D., Green, D., Hassell, D. and Paterson, K., 1993: Getting started with GIS, in *Teaching Geography*, April, 55060.

Freeman, D., Green, D. and Hassell, D., 1994: A guide to Geographic Information Systems (GIS), in *Teaching Geography*, January, 36-7

Friedman, T., 2005: *The World Is Flat: A Brief History of the Twenty-First Century*, Farrar, Strauss & Giroux, New York.

Fullan, M., 1995: *Change Forces*, Falmer Press, London.

G

Gagné, R. M. and Briggs, L. J., 1974: *Principles of Instructional Design*, Holt, Rinehart and Winston, New York.

Gartrell, J., 1996: Geographic Information Systems in the classroom: Geography at West Hill Secondary School with GIS and more..., in *The Monograph*, 47(1), 21-22

Gallé, E. and Reyes, J., 2005: How do Hungarian pupils and teachers use thematic maps in elementary school?, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 137-142.

Galloway, B., 1997: Schools of thought – putting GIS on the curriculum, in *Mapping Awareness*, 11(3), 32-34.

Gardner, H., 1985: *Frames of Mind*, Basic Books, New York.

Garra, A. M., de Moretti, C. J. and Rey, C. A., 2003: Risks and natural disasters to teach from geography and cartography, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Garris, R., Ahlers, R. and Driskell, J. E., 2002: Games, motivation, and learning: a research and practice model, in *Simulation & Gaming*, 33(4), 441-467.

Geography Education Standards Project, 1994: *Geography for Life: National Geography Standards 1994*, Washington DC. (National Geographic Research and Exploration conducted on behalf of the American Geographical Society, the Association of American Geographers, the National Council for Geographic Education, and the National Geographic Society.)

Gerber, R.V., 1984: Factors affecting the competence and performance in map language for children at the concrete level of map reasoning, *Cartography*, 13(3), 205-213.

Gerber, R.V., 1996: Directions for research in geographical education: the maturity of qualitative research, in R. Gerber and J. Lidstone, (eds) *Developments and Directions in Geographical Education*, Channel View Publications, Clevedon.

Gerber, R., 2006: An internationalised, globalised perspective on geographical education in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, Brisbane, 14 – 26.

Gerber, R. and Lidstone, J., 1996: Reflecting on developments and directions in geographical education in R. Gerber and J. Lidstone (eds) *Developments and Directions in Geographical Education*, Channel View, Clevedon, 1-11.

Gerber, R. and Wilson, P., 1984: Maps in the classroom, in J. Fein, R. Gerber and P. Wilson (eds) *The Geography Teacher's Guide to the Classroom*, Macmillan, Sydney, 146-157.

Gill, S. and Roberts, P., 1998: GIS in every high school in Powys, Ordnance Survey Education, available at http://www.o-s.uk/educate/mapnews/powys.htm.

Gould, P. R., 1973: On mental maps in R. M. Downs and D. Stea (eds) Image and Environment, Edward Arnold, London, 182-220.

Government Gazette, 2000: Promotion of Access to Information Act 2000.2 in *Government Gazette* number 20852 5, Government Printer, Pretoria.

Graves, N.J., 1982: The evaluation of geographical education in N. J. Graves (ed) *New Unesco Source Book for Geography Teaching*, Longman/The Unesco Press, 313 – 363.

Green, D. R., 1991: GIS software for schools: what about it?, in *Mapping Awareness*, 5(9), November, 34-36.

Green, D. R., 1992: GIS in secondary education: recent developments in the US and UK, in *Mapping Awareness and GIS in Europe*, 6(4), May, 72-73.

Green, D. R. 2001a: GIS in School Education: An introduction, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 1 – 25.

Green, D. R. 2001b: GIS in School Education: You don't necessarily need a microcomputer, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 34 – 61.

Green, D. R., 2001c: Geography, GIS and the Internet, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 151 – 166.

Griffin, D. R., 1973: Topographical orientation, in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London,296-299.

Grigorenko, E. L., 2000: Heritability and intelligence, in R. J. Sternberg (ed.), *Handbook of Intelligence*, Cambridge University Press, New York, 53-59.

Guelke, L., 1979: Perception , meaning and cartographic design, *The Canadian Cartographer*, 16(1), 107-122.

H

Handoyo, Y. S., 2005: Children's cognition on the World Map Competition, an Indonesian case, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 169.

Hanekom, D., Minister for Agriculture and Land Affairs, 1998*: Address to the National Assembly on the Occasion of the Budget Vote of the Department of Land Affairs*, 23 April 1998, Cape Town.

Hanewinkel, C. and Tzschaschel, S. 2005: Teaching with animated maps – the use of the German National Atlas for schools, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 125-130.

Hart, R.A. and Moore, G.T., 1973: The development of spatial cognition: A review in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 246-288.

Hassell, D., 1996: Using IT in coursework, *Teaching Geography*, 21(2), 77-80.

Hassell, D., 2002: Issues in ICT and Geography, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 148-159.

Herzig, R. and Jarausch, H., 2003: Development of cartographic and spatial comprehension by children – an investigation about Barbara Petchenik children's map competition, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Herzig, R., 2006: Problems of GIS didactics for general school in Germany, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 206-211.

Hernstein, R. J. and Murray, C., 1994: *The Bell Curve*, Free Press New York.

Hicken, E., 2008: GIS (Geographical Information Systems) as a facilitation tool for sustainable development in Africa, paper presented at the Global Dialogues on Emerging Science and Technology (GDEST) Conference, 17-19 March, Cape Town.

Hodgkiss, A.G., 1981*: Understanding Maps a Systematic History of Their Use and Development*, Dawson, Folkstone.

Hofmeyer, J. and Buckland, P., 1992: Education system change in South Africa, in R. and A. McGregor (eds) *McGregor's Education Alternatives*, Juta, Cape Town, South Africa (15-59).

Holmes, D., 1996: Visualisation software: a new aid to learning, in *Teaching Geography*, 21(1), 17-19.

Howie, S. J., Muller, A. and Paterson, A., 2005: *Information and Communication Technologies in South African Secondary Schools*, HSRC Press, Cape Town.

Hull, D., 2001: The impact of the South African Qualifications Authority Act on Surveying qualifications, Plato and the registration process, paper presented at CONSAS 2001 (Conference of South African Surveyors), Cape Town.

Hurn, J., 1989: *GPS A Guide to the Next Utility*, Trimble Navigation, Sunnyvale, California.

Huysaman, G.K., 1994: *Methodology for the Social and Behavioural Sciences*, Southern Publications, Halfway House, South Africa.

I

Ida, Y., 2006: The meaning of geography education using GIS in Japanese junior high schools, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 217-220.

IDRISI, 1996: IDRISI use expands in schools, *IDRISI News*, 8(1), Fall, page 15.

IDRISI, 1998: IDRISI in schools, available at http://www/idrisi.clarku.edu/o7school/main.htm

Innes, L. M., 1995: The implications of the 'new style' South African 1:50 000 topographic map for teaching map reading, paper presented at the First International Geography Conference, of the joint Society of South African Geographers, Durban.

Innes, L.M., 1997: Are you Map Aware?, *LANDinfo*, DLA, 4(6), 24-25.

Innes, L. M., 1998: Learning to read the South African 1:50 000 topographic map: the development of a self-instruction method, unpublished M.Ed. dissertation submitted to the Faculty of Education, University of the Witwatersrand, Johannesburg.

Innes, L. M., 1999a: The role of Geography education in developing map literacy in South Africa, paper presented at the 3rd Biennial SSAG (Society of South African Geographers) Conference, Windhoek, Namibia.

Innes, L. M., 1999b: Map literacy: putting the G into GIS, paper presented at the EDIS (Earth Data Information Systems) Conference, Pretoria.

Innes, L. M., 1999c: MapAware and environmental education: improving map literacy together, paper presented at the Annual EEASA (Environmental Education Association of South Africa) Conference, Grahamstown.

Innes, L.M., 1999d: First steps towards map literacy for all in South Africa, *International Cartographic Association Newsletter*, August 1999.

Innes, L.M., 2000: *MapTrix, a self-instruction programme for learning to read the 1:50 000 Topographic Map of South Africa*, Juta, Cape Town.

Innes, L. M., 2002: Evaluating learning materials for map reading, paper presented at the Regional Conference of the IGU (International Geographical Union), Durban, South Africa.

Innes, L. M., 2003a: MapTrix, in *International Research in Geographical and Environmental Education*, 12(4), 376-382.

Innes, L. M., 2003b: Maths for map users, paper presented at 21st ICA (International Cartographic Association) Conference, Durban, South Africa.

Innes, L. M., 2003c: The impact of school mathematics and geography teaching on topographic map use performance, paper presented at the 5th biennial SSAG (Society of South African Geographers) Conference, Bloemfontein, South Africa.
Innes, L. M., 2005: Identifying spatial competence outcomes for South African Secondary Schools, paper presented at ICC 2005, A Coruña, Spain.
Innes, L. M. and Engel, B., 2001a: Map literacy training, paper presented at CONSAS 2001 (Conference of South African Surveyors), Cape Town.
Innes, L. M. and Engel, B., 2001b: The role of the national mapping organisation in map literacy education and training, paper presented at the 4th biennial SSAG (Society of South African Geographers) Conference, Goudini Spa, South Africa.
Institut Cartogràfic de Catalunya, 1997: 15 713 422 distributed sheets of the Mapa comarcal de Catalunya 1:50 000 Cartographic divulging record in Catalonia, *Newsletter of the Institut Cartogràfic de Catalunya*, 2, 1.
Institute for Soil, Climate and Water, 2001: Article from Africa in *GEOEurope*, 10(6), 16.
International Geographical Union Commission on Geographical Education (IGU CGE), 1992: *International Charter on Geographical Education*, IGU, Brisbane.

J

Jacobs, J. A. and Smit, H. A. P., 2001: The topographic challenge of the South African National Defence Force, poster presented at the 4th biennial SSAG (Society of South African Geographers) Conference, Goudini Spa, South Africa.
Jansen, J. and Christie, P. (eds), 1999: *Changing Curriculum: Studies on Outcomes-Based Education in South Africa*, Juta, Kenwyn, RSA.
Johnston-Anumonwo, I., 2006: Defusing ethnocentrism: teaching the cultural geography of Africa, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 228-232.
Jonassen, D. H., 1992: Evaluating constructivistic learning in T. M. Duffy and D. H. Jonassen (eds) *Constructivism and the Technology of Instruction: A Conversation*, Lawrence Erlebaum Associates, New Jersey.
Jones, M, 2006: Geographical Information Systems – mapping abstract phenomena in *Khanya, Education Through Technology*, Western Cape Education Department, (9), 16-19.
Joyce, P., (ed.) 2004: *World Atlas for South Africans*, Jonathan Ball, Johannesburg.

K

Kagan, J., 1964a: *Developmental Studies of Reflection and Analysis*, Harvard University Press, Cambridge, MA.
Kagan, J., 1964b: Impulsive and reflective children in J. D. Krumbolz (ed.), *Learning and the Educational Process*, Rand McNally, Chicago.
Kallaway, P., 1984: An introduction to the study of Education for Blacks in South Africa, in P. Kallaway (ed.) *Apartheid and Education*, Ravan, Johannesburg, 1-44.
Kankaanrinta, I., Komulainen, E. and Houtsonen, L., 2006: Geographical Information Systems in schools and self-rated Multiple Intelligences, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 233-237.
Kaplan, S., 1973: Cognitive maps in perception and thought in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 63-78.
Kasadde, C. A., 2008: Land use change and local people's perception of the effects of change in Ssese Islands, Uganda, paper presented at the Global Dialogues on Emerging Science and Technology (GDEST) Conference, 17-19 March, Cape Town.

Kerski, J. J., 2003: The implementation and effectiveness of geographic information systems technology and methods in secondary education, in *Journal of Geography*, 102(4), 128-137.

Kerski, J. J., 2008: Toward an international geospatial education community, in A. J. Milson and M. Alibrandi (eds), *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, Information Age Publishing, Charlotte, NC, 61-74.

Khanya, 2005: Khanya launches the laptop/data projector Mathematics pilot project, accessed on 13 July 2008 from http://www.khanya.co.za.news/events/?pageid=73.

Kitao, S. K., 1989: *Reading, Schema Theory and Second Language Learners*, Eichosha Shinsha, Tokyo.

Knox, J. C., 1958: The historical development of Geography as a subject in the schools of the Cape Province, 1772-1951, unpublished M.Ed. Thesis, Rhodes University.

Kohn, C. F., 1982: Real problem-solving in N. J. Graves (ed.) *New Unesco Source Book for Geography Teaching*, Longman/The Unesco Press, 114-140.

Konečný, M. and Švancara, J., 1996: (A)perception of the maps by Czech school children, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, (137-146).

Kriel, L.P., 1993a: Die Posisie van aardrykskunde in 'n kurrikulummodel vir onderwys in Suid-Afrika, *South African Geographer*, 20(1/2), 142-147.

Kriel, L.P., 1993b: The national curriculum model and geography: status, content and challenges, paper presented at a symposium (11 August 1993*), A Future for Geography in Education*, University of Pretoria.

Kwan, T. Y. L., 1996: Understanding children's intuitive experience and their familiar environments in the teaching of maps, in R. Gerber and J. Lidstone, (eds) *Developments and Directions in Geographical Education*, Channel View Publications, Clevedon.

Kwan, T. and Chan, E., 2005: Children's preferential modes of spatial communication, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 161-168.

L

Lambert, D., 1996: Issues in assessment, in P. Bailey and P. Fox (eds), *Geography Teachers' Handbook*, Geographical Association, Sheffield, 187 – 201.

Lambert, D., 2002: Using assessment to support learning, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 123-133.

LaPorte, L. J. and Melcher, D. F., 1997: Terrain Visualization, *Military Review*, 77(5), 75-80.

Lawrence, M., 2006: Getting to the point: reflections on participatory GIS and the use of GPS in classrooms, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 280-285.

Lawton, D., 1997: How to succeed in postgraduate study in N. Graves and V. Varma (eds) *Working for a Doctorate*, Routledge, London, 1-17.

Leaf, C., 2002: *Switch On Your brain with the Metacognitive Mapping Approach*, Truth House Publishing, Rivonia, Johannesburg.

Learning Press, 1997:Geography Mapware (sic.), *Educational Supplement* to *City Press*, 24.08.97.

Leat, D., 1997: Cognitive acceleration in geographical education, in D. Tilbury and M. Williams, *Teaching and Learning Geography*, Routledge, London, 143-153.

Leat, D., 2002: Raising attainment in Geography: prospects and problems, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 134-147.

Lee, T. R., 1973: Psychology and living space in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 87-108.

Lee, T-N., 2006: Education for sustainable development – some observations from Hong Kong, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 286-290.

Legassick, M., 1977: Gold, agriculture and secondary industry in South Africa 1885-1970; from periphery to sub-metropole as a forced labour system, in R. Palmer and N. Parsons (eds) *The Roots of Rural Poverty in Central and Southern Africa*, London (192) (as quoted in Davis, 1993).

Le Grange, L. and Beets, P., 2005: Geography education in South Africa after a decade of democracy, in *Geography*, 90(3), 267-277.

Le Grange, L. and Reddy, C., 2000: Introducing teachers to OBE and EE: a Western Cape case study, in *South African Journal of Education*, 20(1), 28-32.

Liben, L. S. and Bigler, R. S., 2002: The developmental course of gender differentiation: conceptualizing measuring and evaluating constructs and pathways, *Monographs of the Society for Research in Child Development*, 67(2), 1-147.

Lidstone, J., 1988: Research in Geographical Education in R. Gerber and J. Lidstone (eds.), *Developing Skills in Geographical Education*, International Geographical Union, Brisbane.

Liebenberg, E.C., Rootman, P.J. and van Huysteen, M.K.R., 1976: *The South African Landscape*, Butterworth, Durban.

Liebenberg, E.C., 1986 (revised 1992): *Techniques for Geographers, Book 1*, Butterworths, Durban.

Liebenberg, E. C., 1998: Teaching map use in a multicultural environment, *South African Geographical Journal*, 80(2), 111-117.

Link, F. R., 1989: Instrumental enrichment: a strategy for cognitive and academic improvement, in F. R. Link (ed.). *Essays on the Intellect*, Association for Supervision and Curriculum Development, Alexandria, VA.

Linn, M. C. and Petersen, A. C., 1986: A meta-analysis of gender differences in spatial ability: implications for mathematics and science achievement, in J. S. Hyde and M. C. Linn, eds, *The Psychology of Gender: Advances Through Meta-analysis*, 67-101, John Hopkins University Press, Baltimore.

Livieratos, E., 1996: On some fundamental cognitive issues in cartographic education, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, (15-18).

Livni, S. and Bar, V., 2005: A controlled mapping experiment on teaching Earth Science concepts, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 41-42.

Lloyd, 1997: *Spatial Cognition: Geographic Environments*, Kluwer Academic Publishers, Dordrecht.

Lötter, J.P.K., 1997a: The schooling system and university admission in South Africa, paper tabled at a meeting (17-18 March 1997) with Lesotho Education Representatives, Matriculation Board, Pretoria.

Lötter, J.P.K., 1997b: Minimum general university admission requirements in South Africa, paper tabled at a meeting (30 July 1997) with Danish Education Representatives, Matriculation Board, Pretoria.

Lotz, H. B., 1996: The Development of Environmental Education Resource Materials for Junior Primary Education through Teacher Participation: The Case of the We Care Primary Project, unpublished D.Ed dissertation, University of Stellenbosch.

Lotz, H., Tselane, T and Wagiet, R., 1998: *Supporting Curriculum 2005: Developing Learning Programmes with 'Environment' as Phase Organiser*, Department of Environmental Affairs and Tourism for the Environmental Education Curriculum Initiative (EECI), Pretoria.

Lundall, P. and Howell, C., 2000: *Computers in schools: A national survey of Information Communication Technology in South African schools*, Education Policy Unit, University of the Western Cape and the International Development Research Centre, Cape Town.

Lynch, K., 1973: Some references to orientation in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 300-315.

M

MacEachren, A. M., 2004: *How Maps Work: Representation, Visualization and Design*, Guilford Press, New York.

Magi, L. M., 1981: Black university geography students' perception of school geography and the geography teacher, *South African Geographer*, 9(2), p145-153.

Maguire, D. J., 1989: The Doomsday Interactive Videodisc System in geography teaching, in *Journal of Geography in Higher Education*, 13(1), 55-68.

Maguire, M., 2006: Spatial Technologies in Schools (STiS) and the spatial industry in Queensland – "It Takes a Whole Village to Raise a Child" (African Proverb), in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 297-302.

Majtenyi C., 2008: Rwanda strives to become high technology hub for Africa, *Voice of America*, 3 June 2008 (available on www.NewsVOA.com).

Malone, L., Palmer, A. M. and Voigt, C. L., 2003: *Community Geography: GIS in Action - Teacher's Guide*, ESRI Press, Redlands, California.

Maree J. G. and Fraser, W. J., 2004: *Outcomes-based Assessment*, Heineman, Sandown, RSA.

Martin, C., 2008: GIS and the geography curriculum in *PositionIT*, GISSA Journal, May/June 2008, 10.

Matandela, M., 2008: Technology adds up, in *Khanya: Education Through Technology*, Western Cape Education Department, (13), 18-19.

Matengu, K. K., 2006: *Adoption of ICT at Schools in Core and Periphery Settings of Namibia: Exploring Innovation, Technology Policy and Development Issues*, Geowissenschaft Shaker Verlag, Aachen.

McAnneny, C and Bampton, M., 2006: Identifying fundamental barriers to learning in GIS, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 303.

McCown, R., Driscoll, M. and Roop, R. G., 1996: *Educational Psychology: a Learning Centred Approach to Classroom Practice*, Allyn and Bacon, Needham Heights, Massachusetts.

McGee, O., Grant, L. and Madikizela, N., 1995: Teaching geography to under-prepared students in South African universities: the Pietermaritzburg experience, paper presented at the first International Geography Conference of the Society for South African Geographers (SSAG), Pietermaritzburg, South Africa.

McMaster, A., Motteux, N. and Rowntree, K., 2001: GIS in participatory research: a case study of the Kat River Valley, Eastern Cape, paper presented at SSAG Conference, Goudini, 2001.

Meissner, W., 1996: Teaching material for cartographic education and training of children, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, (97-111).

Michaelidou, E., Nakos, B. and Filippakopoulou, V., 2003: Spatial knowledge acquisition in children of different cultures, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Mihályi, B., 2005: Military history in educational atlases, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 119-124.

Milson, A. J. and Alibrandi, M. (eds) 2008: *Digital Geography: Geospatial Technologies in the Social Studies Classroom*, Information Age Publishing, Charlotte, NC.

Min, W. and Dongying, W., 2006: Intercultural dialogue on educational approaches to sustainable development: China, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 304-308.

Ministry of Education, 1997: Call for comments on the draft statement on the National Curriculum for Grades 1-9, *Government Gazette*, 18051(788), Pretoria, 1-256.

Moallem, M., 2001: Applying constructivist and objectivist learning theories in the design of a web based course: implications for practice in *Educational Technology and Society*, 4(3), 113-125.

Morgan, A., 2006: Developing geographical wisdom: postformal thinking about, and relating to, the World, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 319-323.

Morgan, A. and Freeman, D., 2006: Firing geographical imaginations: finding a place for children's geographical education, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 324-328.

Muehrcke, P.C., 1978: *Map Use, Reading, Analysis and Interpretation*, J P Publications, Madison.

N

Naish, M.C., 1982: Mental development and the learning of geography in N. J. Graves (ed) *New Unesco Source Book for Geography Teaching*, Longman/The Unesco Press, 16-54.

Naish, M., 2002: Action research for a new professionalism in geography education, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 306-322.

Naish, M., Kent, A. and Rawling, E., 1979: The man-environment approach to geography, *Journal of Environmental Education*, 10(June), 48-54.

Naish, M., Rawling, E. and Hart, C., 2002: The enquiry-based approach to teaching and learning Geography, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 63-69.

National Centre for Geographic Information and Analysis (NCGIA) 1993a: GIS in the schools, in NCGIA Newsletter, May 2 pages

National Centre for Geographic Information and Analysis (NCGIA) 1993b: GIS in the schools, in NCGIA Newsletter, November, 4 pages

National Council for Education Technology (NCET) and Geographical Association (GA), 1994: *Geography: A Pupil's Entitlement to IT*, NCET, Coventry.

National Research Council (NRC), 2006: *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, National Academy of Sciences, Washington.

Ndlwana, M., 1991: A Critical Analysis of Problems Encountered by Senior Secondary School Pupils in the Reading and Interpretation of 1:50 000 Topographical Maps and Aerial Photographs with Special Reference to Black Pupils in Transkei, unpublished M.Ed. thesis, Rhodes University, Grahamstown, South Africa.

Nel, E. and Binns, T., 1999: Changing the Geography of apartheid education in South Africa, in *Geography*, 84(2), 119-128.

Nelson, 2000: Designing effective bivariate point symbols: the influence of perceptual grouping processes, in *Cartography and Geographic Information Science*, 27, 261-278.

Newell, R., 1997: GIS in schools, in Geographic Information – The Newsletter of The Association for Geographic Information, 7(1), January, 12.

Nicholson, J. M. and Morton, J. G., 1957: *Man's Environment (Part Three)*, Shuter and Shooter, Pietermaritzburg.

Nicholson, J. M. and Morton, J. G., 1958 (2nd ed.): *Man's Environment (Part One)*, Shuter and Shooter, Pietermaritzburg.
Nicholson, J. M. and Morton, J. G., 1967 (1st ed.), 1974 (3rd ed.): *Working With Maps*, Shuter and Shooter, Pietermaritzburg.
Nxele, A., 2005: The impact of the transition from Grade 7-9 to FET (Grade 10-12) on the teaching and learning of Geography in Eastern Cape schools, paper presented at the 6th biennial SSAG (Society of South African Geographers) Conference, Port Elizabeth, South Africa.

O

Oblinger, D. G., 2004: The next generation of educational engagement, in Journal of Interactive Media in Education, 2004(8), 1-18.
Okpala, J. I. N., 1989: Talking and problem-solving: Reality orientated problem solving questions: A strategy for inducing productive verbalization for externalizing and correcting misconceptions in map work in secondary schools, in F. Slater (ed.) *Language and Learning in the Teaching of Geography*, Routledge, London, 71-91.
Oliver, M., 1992: Computers in your geography programme, in *The Monograph*, 43(3), 16.
Oliver, M., 1993: Geography meanders into the 21st Century – early, , in *The Monograph*, 44(3), 20-21.
Oliver, M., 1994: A summer institute for geography educators, in *The Monograph*, 45(2), 14-15.
Oliver, M., 2001: GIS in secondary school geography curricula, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London page 87-93.
Ordnance Survey, 1999: Ordnance Survey: Geographic Information System (GIS), available at http://www.doeni.gov.uk/ordnance/gised.htm.
Ordnance Survey, 2004: Ordnance Survey announces Britain's biggest geography giveaway, International Map Trade Association, MapReport, 22(5), (16).
Ormeling, F., 1996a: Teaching map use concepts to children, paper presented at ICA Seminar on *Cognitive map, Children and Education in Cartography*, Gifu, International Cartographic Association.
Ormeling, F., 1996b: Realities of teaching cartography in the developing world, *Cartographica*, 33(3), 33-38.
Osmond, C., 2004: Assessment in Social Science education, in J. G. Maree and W. J. Fraser, *Outcomes-based Assessment*, Heineman, Sandown, 221-241.
Ottichilo, W., 2008: Review and future potential of the Regional Centre for Mapping of Resources for Development (RCMRD) in Kenya, keynote address at Global Dialogues on Emerging Science and Technology (GDEST) Conference, 17-19 March, Cape Town.
Ottosson, T. 1988: What does it take to read a map?, *Cartographica*, 25(4), 28-35.
Owen, D., 2003: Collaborative electronic map creation in a UK 5-11 primary school: children's representation of local space and the role of peer and teacher scaffolding in this process, paper presented at 21st International Cartographic Conference, Durban, South Africa.
Owen, D., 2005: Observing computer based mapping activity: a review of research approaches, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 195.

P

Page, J., Williams, G. and Rhind, D., 2001: Geographical information in schools, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London page 26 – 33.
Pakula Shlomi, D., 2005: Web atlas versus hard-copy atlas – reading and comprehension of cartographic information, paper presented at the International Cartographic Association's Joint ICA Commissions Seminar in Madrid, 6 - 8 July 2005, 111 - 118.
Palladino, S. and Goodchild,M. F., 1993: A place for GIS in the secondary schools? Lessons from the NCGIA Secondary Education Project, in Geo Info Systems, April.

Palladino S. and Zuyle, P., 1996: Critical issues in GIS-based educational Module Development: NCGIA's ArcView-based Colour Your World Module, in *Technical Report 96-6*, NCGIA, Santa Barbara, California.

Papadopoulos, K., Tsioukas, V. and Daniil, M., 2003: 3D maps for children's education: multimedia and virtual reality, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Passini, E. Y., Machado, A., Mendes, C. M., Bisneto, D. C., de Paula Santil, F. L., Bueno, J. P., Pezzato, J. P., Rocha, M. M., da Conceição, O. L., Bado, S. R., Malysz, S. T. and Thomaz, S. L., 2003: Municipal atlas of Maringa: studying the local geography, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Pateni, C.N., 1997a: Putting education on the map, *Geoinformation Africa*, 1(1).

Pateni, C.N., 1997b: The role of cartography in a developing country like South Africa :A look at the need for the education of black professional and technical cartographers to drive the mapping process in South Africa in fulfilment of the objectives of the reconstruction and development programme (RDP), *Proceedings 18th ICA/ACI International Cartographic Conference*, Swedish Cartographic Society, Gävle.

Pease, A. and Pease, B., 1999: *Why Men Don't Listen and Women Can't Read Maps*, Pease Training International, Mona Vale, Australia.

Petersen, M. P., 1985: Evaluating a map's image, *The American Cartographer*, 12(1), 41-55.

Petersen, M., 2005: The search engine map landscape, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 21-27.

Piaget, J and Inhelder, B., 1956: *The Child's Construction of Space*, Routledge and Kegan Paul, London.

Piaget, J., 1955: *The Child's Construction of Reality*, Routledge and Kegan Paul, London.

Piaget, J., 1964: Development and learning, in R. E. Ripple and V. N. Rockcastle (eds), *Piaget Rediscovered*, Cornell University Press, Ithica, 7-19.

Potgieter, D. and Olën, S., 1993: The view from above: Map reading skills project, *International Information and Library Review*, 25, 259-271.

Pravda, J., 1996: Two stages in the development of cognitive conception in cartography, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, (46-49).

Price, M. F. and Heywood, D. I., (eds) 1994: *Mountain Environments and Geographic Information Systems*, Taylor & Francis, London.

Prince, M., 2004: Does active learning work? A review of the research, in *Journal of Engineering Education*, 93(3), 223-231.

R

Raadam, T., 1989: Traditional Danish practice in cartographic learning, in R. Gerber and J. Lidstone (eds.), *Developing Skills in Geographical Education*, International Geographical Union, Brisbane, 84-89.

Ramutsindela, M F., 2002: The perfect way to ending a painful past? Makuleke land deal in South Africa, in *Geoforum*, 33, 15-25.

Rhind D., 1993a: Maps , information and Geography: a new relationship, in *Geography*, 78(2) No. 339, 150-159.

Rhind, D., 1993b: Ordnance Survey and schools, in *Teaching Geography*, 18(1), 18-19.

Ritchhart, R. and Perkins, D. N., 2005: Learning to think: The challenges of teaching thinking, in K. J. Holyoak, and R. G. Morrison, (eds), *The Cambridge Handbook of Thinking and Reasoning*, Cambridge University Press, New York, page 775 – 802.

Rhys, W. T., 1972: Geography and the adolescent, *Educational Review*, 24(3), 183-196.

Roberts, M., 2002a: The role of research in supporting teaching and learning, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 283-292.
Roberts, M., 2002b: Curriculum planning and course development, in M. Smith (ed.), *Teaching Geography in Secondary Schools*, Routledge Falmer, London, 70-82.
Roberts, M., 2006: Shaping students understanding of the world in the geography classroom, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 372-376.
Robertson, M. and Fluck, A., 2006: Constructing futures: connected, 'always on' and mobile space, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 377-381.
Robinson, A.H. and Petchenik, B.B., 1975: The map as a communication system, *The Cartographic Journal*, 12(1), 7-15.
Robinson, O. and Thornton, B., 1995: Critical thinking and computers: a natural combination, in *The Monograph*, 46(3), 17-21.
Rüther, H., 2003: The situation of geomatics education in Africa – an endangered profession, keynote paper presented at 2nd FIG (Federation of International Geomaticians) Regional Conference, Marrakech, Morocco.
Rust, L. and Kindler, R., 2008: Introducing GIS into the South African education market, paper presented at the Free and Open Source Software for Geospatial (FOSS4G) Conference (incorporating the GISSA 2008 Conference,) 29 September-3 October 2008, Cape Town.

S

Sadler, D. R., 1989: Formative assessment and the design of instructional systems, *Instructional Science*, 18, 119-144.
Sandford, H. A., 1980: Directed and free search of the school atlas map, *The Cartographic Journal*, 17(2), 83-92.
Sandford, H.A., 1986: Objectives of school mapwork, *Teaching Geography*, October, 22-26.
Sandford, H. A., 1989: School-based research into pupil's mapwork difficulties and their solution, in R. Gerber and J. Lidstone (eds.) *Developing Skills in Geographical Education*, International Geographical Union, Brisbane, 333-338.
South African Bureau of Standards (SABS), 2004: *South African Design Excellence Award*, Design Institute of South Africa (DISA), a division of the SABS, Pretoria.
South African Certification Council (SAFCERT), 2001: Statement to the news media on the certification of the 2001 matric results, accessed online 2008/06/29 at http://www.info.gov.za/speeches/2001/0112211246p1002.htm.
SAQA, 1995: South African Qualifications Authority Act no. 58 of 1995, (www.saqa.org.za).
SAQA, 1997: *SAQA Bulletin*, South African Qualifications Authority, Pretoria.
SAQA, 2000: *The National Qualifications Framework and the Standards Setting*, South African Qualifications Authority, Pretoria.
Sawicka, E., 1996: Developing skills, in P. Bailey and P. Fox (eds), *Geography Teachers' Handbook*, Geographical Association, Sheffield, 95 – 106.
Scardamalia, M. and Bereiter, C., 2006: Knowledge building: theory, pedagogy, and technology, in K. Sawyer (ed.), *Cambridge Handbook of the Learning Sciences*, Cambridge University Press, New York, 97-118.
Sekete, P. G. I., 1995: An investigation into problems with topographic map comprehension by first year college of education students in North West (Province), unpublished Master of Science research report, University of the Witwatersrand, Johannesburg.
Sharpe, B. and Best, A. C., 2001: Teaching with GIS in Ontario's secondary schools, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 73 – 86.

Sheppard, S., 1995: Implementing IT is schools, in *Teaching Geography*, 20(1), 17-19.

Shingareva, K. B. and Krasnopevtseva, B. V., 2005: Cartographic support for school course of Geography of extraterrestrial territories, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 99-104.

Siegel, A. W. and Cousins, J. H., 1985: The symbolizing and symbolized child in the enterprise of cognitive mapping, in R. Cohen (ed.) *The Development of Spatial Cognition*, Lawrence Erlbaum Associates, Hillsdale, page 347 – 368.

Siegel, A. W. and White, S. H., 1975: The development of spatial representations of large-scale environments, in H. W. Reese (ed.), *Advances in Child Development and Behaviour*, *Volume 10*,Academic Press, New York.

Silberstein, S., 1987: Let's take another look at reading: Twenty-five years of reading instruction, *English Teaching Forum*, October, 29-35.

Skuy, M., (ed.) 1993: *Illustrating Feuerstein's Instrumental Enrichment Programme Working Manual*, Cognitive Research Programme, Division of Specialised Education, University of Witwatersrand, Johannesburg.

Smit, T. 1994: The reading of topographical maps – an elementary model for secondary schools, paper presented at the IGU Conference (September 1994), Prague and published in *Geographiedidaktishe Forschungen*, 25.

Smith, J. S., 1974: Development and rural conservation in Easter Ross, *Scottish Geographical Magazine*, 90(1), 42-56.

Smith, F., 1985: *Reading*, Cambridge University Press, Cambridge.

Smith, G., 1994: GIS and Secondary Education in OS, in D. R. Green, D. Rix and J. Cadoux-Hudson (eds), *Geographic Information 1994 The Sourcebook*, Taylor & Francis, London, 336-339.

Snider, V. E., 1990: What we know about learning styles from research in special education in *Educational Leadership*, 48 (2), 53.

Spencer-White, E.M, 1999: National User Needs Survey for Spatial Information and Mapping Products, conducted by Linkin for the Chief Directorate: Surveys and Mapping, Cape Town.

Spencer-White, E.M., 1998: MapAware Roadshow Workshop Programme, report by Linkin for the Chief Directorate: Surveys and Mapping, Cape Town.

Stadler, W., (unacknowledged) 2001: Developing a GIS-based methodology for public health screening, *GEOEurope*, 10(6), 41-42.

Stea, D. and Blaut, J.M., 1973a: Toward a developmental theory of spatial learning in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 51-62.

Stea, D. and Blaut, J. M., 1973b: Some preliminary observations on spatial learning in school children, in R. M. Downs and D. Stea (eds) *Image and Environment*, Edward Arnold, London, 226-234.

Sternberg, R. J., 1987: Teaching Intelligence: the application of cognitive psychology to the improvement of intellectual skills, in J. B. Baron and R. J. Sternberg (eds), *Teaching Thinking Skills: Theory and Practice*, Freeman Press, New York, 182-218.

Sternberg, R. J., 2005: Intelligence, in K. J. Holyoak and R. G. Morrison, (eds), *The Cambridge Handbook of Thinking and Reasoning*, Cambridge University Press, New York, page 751-773.

Stiggins, R. J., 1994: *Student-centered Classroom Assessment*, New York, Merrill-Macmillan.

Stott, D., 2004: A framework for evaluating instructional design models resulting in a model for designing and developing computer based learning tools with GIS technologies, unpublished Master of Education thesis, Rhodes University, Grahamstown.

T

Tam, 2000: Constructivism, instructional design and technology: implications for transforming distance learning in *Educational Technology and Society*, 3(2), 50-60.

Tanaschuk, T., 2001: What's in a picture? *GEOEurope*, 10(6), 32-33

Taylor, H. A. and Tversky, B., 1992: Descriptions and depictions of environments, in *Memory and Cognition*, 20, 483-496.

Taylor, H. A. and Tversky, B., 1996: Perspective in spatial descriptions, in *Journal of Memory and Language*, 35, 371-391.

Tengbeh, G. T., 2004: South Africa: an unknown country to its geography students?, in *South African Geographical Journal*, 86(2), 76-84.

Thomas, M. S. C. and Karmiloff-Smith, A., 2004: Modeling typical and atypical cognitive development: Computational constraints on mechanisms of change, in U. Goswami, (ed.) *Blackwell Handbook of Childhood Cognitive Development*, Blackwell, Oxford, page 575 – 599.

Thurston, L. L., 1938: *Primary Mental Abilities*, University of Chicago Press, Chicago.

Tickner, P., 2000: South Africa's National Mapping Organisation celebrates 80 years of service excellence, *International Cartographic Association Newsletter*, December, 2000, 3-4.

Transvaal Education Department, 1983: *Final Core Syllabus for Geography Standards 8, 9 and 10* (for implementation 1985, 1986 and 1987), Transvaal Education Department, Pretoria.

Treib, M., 1980: Mapping experience, in *Design Quarterly*, (dedicated annual issue).

Tshibalo, A. E., 2003: Cooperative learning as a strategy to improve the teaching of mapwork to grade 11 and 12 Geography learners in Region 3 (Limpopo Province): a case study conducted at Ramaano Mbulaheni Inservice Training Centre, poster presented at 21st International Cartographic Conference, Durban, South Africa.

Tshibalo, A. E. and Schulze, S., 2000: Co-operative learning in tertiary education: Teaching mapwork to Geography students, *South African Journal of Education*, 20(3), 230-234.

Turner, C. J., 2001: Cadastral and land registration component in land reform implementation, paper presented at CONSAS 2001 (Conference of South African Surveyors), Cape Town.

Turner, C.J. and Parker, A., 1997: Leliefontein a land reform project by the Chief Directorate of Surveys and Mapping, South African Journal of Surveying and Mapping, 24(3), 139-142.

Turner, P. S., 1993: The wider Geography community's contribution to promoting Geography as a school subject: practical initiatives for survival, paper presented at a symposium (11 August 1993*), A Future for Geography in Education*, University of Pretoria.

Tversky, B., 1993: Cognitive maps, cognitive collages, and spatial mental models, in A. U. Frank and I. Campari (eds), *Spatial Information Theory: A Theoretical Basis for GIS*, Springer-Verlag, Berlin, 14-24.

Tversky, B., 2005: Visuospatial Reasoning, in K. J. Holyoak, and R. G. Morrison, (eds), *The Cambridge Handbook of Thinking and Reasoning*, Cambridge University Press, New York, page 209 – 240.

U

Unewisse, M. H., Gaertner, P. S., Grisogono, A-M. and Seymour, R. S., 1999: Land Situational Awareness for 2010, paper presented at SimTecT (Simulation Technology and Training Conference) 1999, Melbourne, Australia.

V

van der Merwe, A. J., 1982: Geography in the South African curriculum in relation to developments in the teaching of the subject overseas, unpublished M.Ed. Thesis, Rhodes University.

van der Post, C., 2008: Integrated data for integrated planning for the Okavango Ramsar Site: challenges and prospects, paper presented at the Global Dialogues on Emerging Science and Technology (GDEST) Conference, 17-19 March, Cape Town.

van der Schee, J., 1989: Thinking Geography with maps, in R. Gerber and J. Lidstone (eds.), *Developing Skills in Geographical Education*, International Geographical Union, Brisbane, 76-79.

van der Schee, J., 2003: New media will accelerate the renewal of geographical education, in R. Gerber (ed.), *International Handbook on Geographical Education*, Kluwer, Dordrecht, 205-214.

van der Schee, J., Vankan, L and Leat, D, 2003: The international challenge of more Thinking Through Geography, in *International Research in Geographical and Environmental Education*, 12(4), 330-343.

van der Schee, J., 2006: EduGIS - a challenge for geography teaching, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 452-456.

van der Westhuizen, C. P. and Richter, B. W., 2006: The DVD as ICT-variant for geography teaching and learning, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 457-462.

Van Harmelen, U., 1999: Where has all the Geography gone? A social constructivist perspective of Curriculum 2005, in *South African Geographical Journal*, 81(2), 80-85.

van Wyk, K., 2006: Unlocking the computer room in *Khanya, Education Through Technology*, Western Cape Education Department, (9), 6-7.

Virvou, M., Katsionis, G. and Manos, K., 2005: Combining software games with education: evaluation of its educational effectiveness, in *Educational Technology & Society*, 8(2), 54-65.

Vlok, A.C., 1992: School desk atlases: South African practice and international trends, *South African Geographer*, 19(1), 146-157.

Vlok, A.C. and Zietsman, S., 2001: Adapt or die: the case of South African Geography at tertiary level, paper presented at the SSAG (Society of South African Geographers) Conference, Goudini, 2001.

W

Wagner, R. K., 2000: Practical Intelligence, in J. R. Sternberg (ed.), *Handbook of Human Intelligence*, Cambridge University Press, New York, 380-395.

Walford, R., 1999: Losing the plot, *Geographical*, 71(12), 28-30.

Walker, D. F., 1976: Toward comprehension of curricular realities, *Review of Research in Education*, 4(1976), 268-308.

Walker, S., 2001: Another school of thought: Introducing GIS to a secondary school geography department, in D. R. Green (ed.) *GIS: A Source Book For Schools*, Taylor and Francis, London, page 127 – 136.

Warner, H., 1994: CD-ROM technology in Geography: potential and issues, *Teaching Geography*, 19(4), 184-185.

Weekend Post, 2007: Intimidation rules at hospitals and schools as Popcru set to join strike, accessed 13 July 2008 from www.weekendpost.co.za/main/2007/06/16/news/nl14_16062007.htm.

Wesso, H. and Parnell, S., 1992: Geography education in South Africa: colonial roots and prospects for change, in C. Rogerson and J. McCarthy (eds) *Geography in a Changing South Africa*, Oxford University Press, Cape Town, (186-200).

West, B. A., 2006: Towards an understanding of conceptions of GIS held by senior geography students in Queensland, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 467-471.

Wiegand, P., 1996: Children's representation of the Earth's land masses on plane and spherical surfaces, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, (81-88).

Wiegand, P., 2003: Using GIS to access school students understanding of choropleth maps, paper presented at 21st International Cartographic Conference, Durban, South Africa.

Wiegand, P., 2005: The best of both worlds: complementarity in educational cartography, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 149-154.

Wiegand, P., 2006a: Better maps: better teaching, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 472-476.

Wiegand, P., 2006b: *Learning and Teaching with Maps*, Routledge, London.

Williams, D., 2005: The Atlas of Canada in education, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 28.

Wilmot, P. D., 1998: Graphicacy as a form of communication in the primary school, submitted in partial fulfilment for M.Ed., Rhodes University.

Wilmot, D., 2005: The development phase of a case study of outcomes-based education assessment policy in the Human and Social Sciences learning area of C2005, in *South African Journal of Education*, 25(2), 69-76.

Wilson, B., Teslow, J. and Osman-Jouchoux, R., 1995: The impact of constructivism (and postmodernism) on ID fundamentals in B. B. Seels (ed) *Instructional Design Fundamentals*: A Reconsideration, Educational Technology Publications, New Jersey, (137-157).

Wilson, D. and Schröder, B., 2007: Creating land cover maps using Landsat TM data, in *PositionIT*, GISSA Journal, Nov/Dec 2007, 48-52.

Winchester, S., 2001: *The Map That Changed the World*, Penguin, London.

Wolf, A., 1995: *Competence-based assessment*, Open University Press, Buckingham (UK).

Wood, M., 1996: Cartography in the new millennium, in T. Kanakubo and K. Kanazawa (eds) *Proceedings of the seminar on Cognitive Map, Children and Education in Cartography*, International Cartographic Association, Japan, 1-10.

Y

Yin, R. K., 1994: Case study research: Design and methods in *Applied Social Sciences Methods Series, Volume 5*, Sage Publications, California.

Young, J. E., 1994: Re-examining the role of maps in geographic education: images, analysis, and evaluation, in *Cartographic Perspectives*, 17 (winter), 10–20.

Z

Zentai, L. and Dombóvári, E., 2005: Edutainment in cartography, in L. Zentai, J. J. R. Nuñes and D. Fraser (eds) *Proceedings of the International Cartographic Association's Joint ICA Commissions Seminar*, Madrid, 6-8 July 2005, 60-65.

Zietsman, H. L., 1999: GIS in African countries: Quo Vadis?, paper presented at the 3rd Biennial International Conference of the SSAG (Society of South African Geographers), Windhoek, Namibia.

Zwartjes, L., 2006: Eduspace: European Earth observation for study of the environment, in K. Purnell, J. Lidstone and S. Hodgson, (eds) *Proceedings of the International Geographical Union Commission on Geographical Education Symposium*, IGU CGE and Royal Geographical Society of Queensland, QUT Publications, 492-497.

Appendix 1.1

REVIEW OF CHANGING GEOGRAPHY SYLLABUSES AND PROVISION FOR MAP USE TEACHING IN SOUTH AFRICA FROM 1839 TO 1970

Clark (1989) traces five phases in geography teaching in South Africa, each triggered by significant paradigm shifts and generally following education trends in England.

- 1839 – 1859

The initial phase lasted about twenty years and was distinguished by descriptive Geography. Mapwork played an important role with pupils encouraged to use and/or draw maps. There was an initial emphasis on the home locality and subsequently the map scale shrank to include the local region or province, the country and the world. During this time a *Junior* and then an *Advanced Atlas for Southern African Schools* were published by Nelson, the latter was hailed by some European educators as one of the best school atlases in the world (Clark, 1998). Although valuable use was made of maps in learning to describe the world, the strong emphasis on memorising place names and products was criticised.

- 1859 - 1910

The second phase from 1859 until the Union of the Cape, Natal, Orange Free State and Transvaal in 1910 was marked by the inclusion of Physical Geography in school syllabuses. Apart from the British trend upon which much of South African teaching practice was based, the inclusion of Physical Geography in examinations for the public service in South Africa gave further impetus to this development. Clark reports on Knox's (1958) review of geography examination papers from this phase where once again the burden of recall was criticised, this time for the memorising of place names as well as rote learning of definitions. The drawing of maps was still emphasised rather than their reading, analysis and interpretation.

- 1910 - 1940

During the next thirty years, until approximately 1940, Clark suggests that two British university lecturers, both members of the Geographical Association and prolific textbook writers made a significant impact on what was being taught in geography classrooms – Mackinder and Herbertson. Their contribution was two-fold: 'the unity of the man-environment relationship, and the adoption of the region as the framework of study' (Clark, 1989: 50). The British influence, which pervaded the education system at the Cape and later the other provinces, became evident when more practical as opposed to descriptive Geography was included in the examinations.

The paradigm in which Geography is seen (according to Clark, 1989) as 'the science of relationships' had a South African adherent in Adamson, Director of Education in the Transvaal who played an important role in 'modernising' geography teaching. During this time, apart from variations between syllabuses for the different provinces, there were a number of different examination boards. However, Clark found many common features: firstly an attempt to match topics with the developmental stages of pupils; secondly the introduction of regional Geography, based on political divisions, at an elementary level; thirdly a focus on natural regions in high school including simple climatology and economic Geography. Unfortunately a mass of detail was introduced and teachers complained of overloading, examiners expressed concern about 'the development of understanding and simple mapping skills' (Clark, 1989: 51).

- 1940 - 1970

Leading up to another phase which started around 1940, Clark (1989) notes that while there was initially a balance between practical, physical and regional Geography, the regional geography section became bloated with the stipulation that more countries should be studied, mainly European or those areas settled by Whites and that there should be a stronger focus on South Africa. This was a reflection of the rise to power of the Nationalist Party which dominated South African politics after 1948.

For the next thirty years or so, the region assumed a dominant position in South African school Geography. The intention was that regions should be investigated by map analysis and (if possible) by field study and that perspectives such as position, relief, climate, vegetation, products, principal towns, industries and transport should be synthesised for each region. In the preface to their series of geography textbooks used in South African secondary schools for many years, Nicholson and Morton (1958) caution that each book 'has been designed for use in conjunction with a good atlas'. In the last book in the three-part series they express the concern that the atlas is 'one of the finest but most neglected books to be found in the school' (Nicholson and Morton, 1957: v).

In an attempt to encourage teachers to use an atlas while teaching regional Geography the introduction to each continent is presented as a series of questions for which answers must be sought in an atlas. Unfortunately no record has come to hand indicating whether these good intentions became common classroom practice and Wesso and Parnell (1992) suggest that lessons during this phase differed little from the rote naming of terms and features that had become common practice. In the foreword to their specialised map use text, Nicholson and Morton (1967) note that 'South African schools have on the whole been relatively slow to adopt the quantitative approach'.

Wesso and Parnell (1992: 191) discuss the implication for geography teaching of the ruling National Party's 1948 policy of imposing Christian National Education on all, regardless of creed. They include a section of a report quoted by Bunting (1986) concerning the content of Geography:

> 'Every nation is rooted in a country allotted to it by God. Geography should aim at giving the pupil a thorough knowledge of his own country and the natural objects pertaining to it, in such a way that he will love his own country, also when compared and contrasted with others, and be ready to defend it, preserve it from poverty, and improve it for posterity.'

By later dismembering South Africa into 'homelands' for different population groups, the implication was that the balance of the country 'belonged' to Whites, allotted to them by a divine power. Blacks on the other hand were to be satisfied with land that the state had allotted to them.

Before 1953, the state was content to leave the responsibility for the education of children of colour in the hands of missionaries but that year the state assumed control of the education of Black children (Davis, 1984) with the passing of the Bantu Education Act. The curriculum of the Department of Education and Training (DET) was designed 'to provide for the mass of Africans the minimum of educational skills necessary for participation in semi-skilled positions in the forced labour economy. Secondly, to attempt to train a small African elite who would seek their economic and political outlets not within the central white-controlled state but in the 'homelands' (Legassick, 1977). The financing of education for children of colour fell far short of that for white children (Davis, 1984). Lack of resources meant that there were few if any maps and atlases available for primary school pupils learning the diluted geography component of Social Studies or for older siblings taking Geography at secondary school. These factors further reduced the chances of adequate performance in map use.

As traced in the brief chronology in 1.4.2, Geography continued to enjoy popularity in White schools and was selected by an increasing number of senior certificate candidates each year. Although percentages of students choosing Geography in each provincial department of education varied, approximately one third of the total chose this elective for the period 1970 to 1985 (Ballantyne, 1987b). Guidelines were suggested for ensuring that this percentage be maintained and where possible increased (Clark, 1989). In contrast, Geography held a poor position in Black schools. Wesso and Parnell (1992) trace this situation to a number of causes including: enforced instruction in Afrikaans in Black schools making terminology difficult to understand and the ethnocentric bias in the geography syllabus favouring the White minority. They also suggest that at teacher training colleges students 'were confronted with a geography with strong ideological and environmental determinist undertones' (Wesso and Parnell, 1992:192) which discouraged Black student teachers from taking the subject. The shortfall in qualified geography teachers in Black schools in turn deepened the spiral of declining interest in the subject.

During the 1960's, a period marked by the formation of the Republic of South Africa, there was an international transformation of Geography 'from the idiographic description of regions to a nomothetic, law-seeking science' (Clark, 1989: 52). Causal relationships and comparisons were sought following the environmental determinism paradigm. Wesso and Parnell (1992) suggest that Afrikaner nationalists embraced this change because they saw this approach as supporting racial supremacy. There was political interference in all aspects of South African endeavour during this time. By way of example: a state grant for the publication of the journal of the South African Geographical Society was made in 1963 on condition that White and Black persons should not attend meetings together. The council of the society, unable to accommodate this proviso, turned down the grant (Fairhurst et al., 2003).

Appendix 1.2

Table A1.2 Provincial breakdown of Higher Grade and Standard Grade mark allocations for the Theory and Practical Geography examination papers for the period 2000 to 2007

SITA Code	Province name	Higher Grade		Standard Grade	
		Theory paper	Practical paper	Theory paper	Practical paper
1	Western Cape*	300	100	225	75
2	Northern Cape*	300	100	225	75
3	Free State*	300	100	225	75
4	Eastern Cape*	300	100	225	75
5	KwaZulu-Natal*	300	100	225	75
6	Mpumalanga**	300	100	225	75
7	Limpopo*	300	100	225	75
8	Gauteng*	300	100	225	75
9	North West‡	300	100	225	75

* Until 2005 the Higher Grade breakdown was 320 and 80 and the Standard Grade breakdown was 240 marks and 60 marks

** Until 2005 the Higher Grade breakdown was 330 and 70 and the Standard Grade breakdown was 250 marks and 50 marks

‡ Until 2001 the Higher Grade breakdown was 320 and 80 and the Standard Grade breakdown was 240 marks and 60 marks

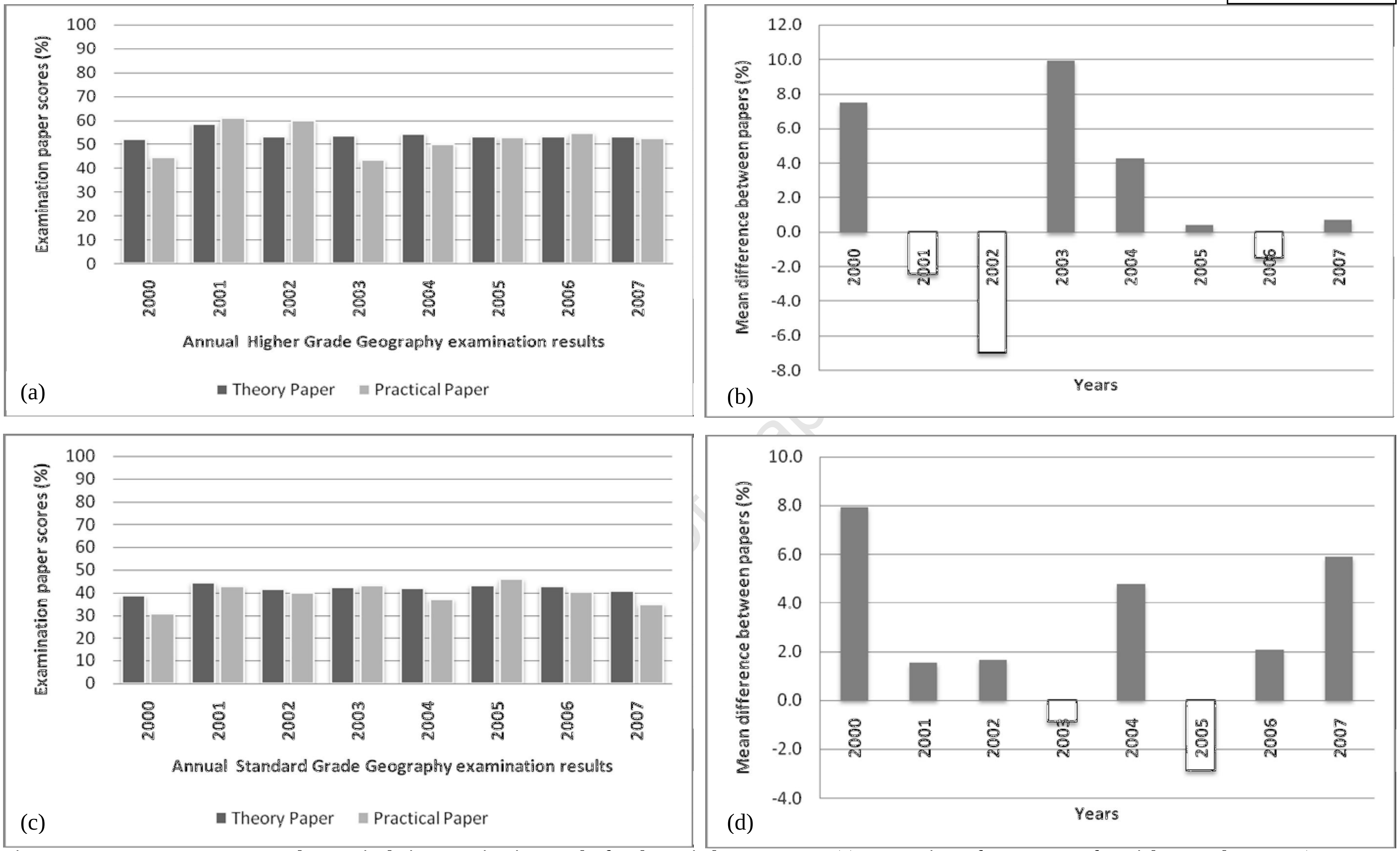


Figure A1.1 Western Cape Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 5 476 to 6 403). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 12 764 to 14 935). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

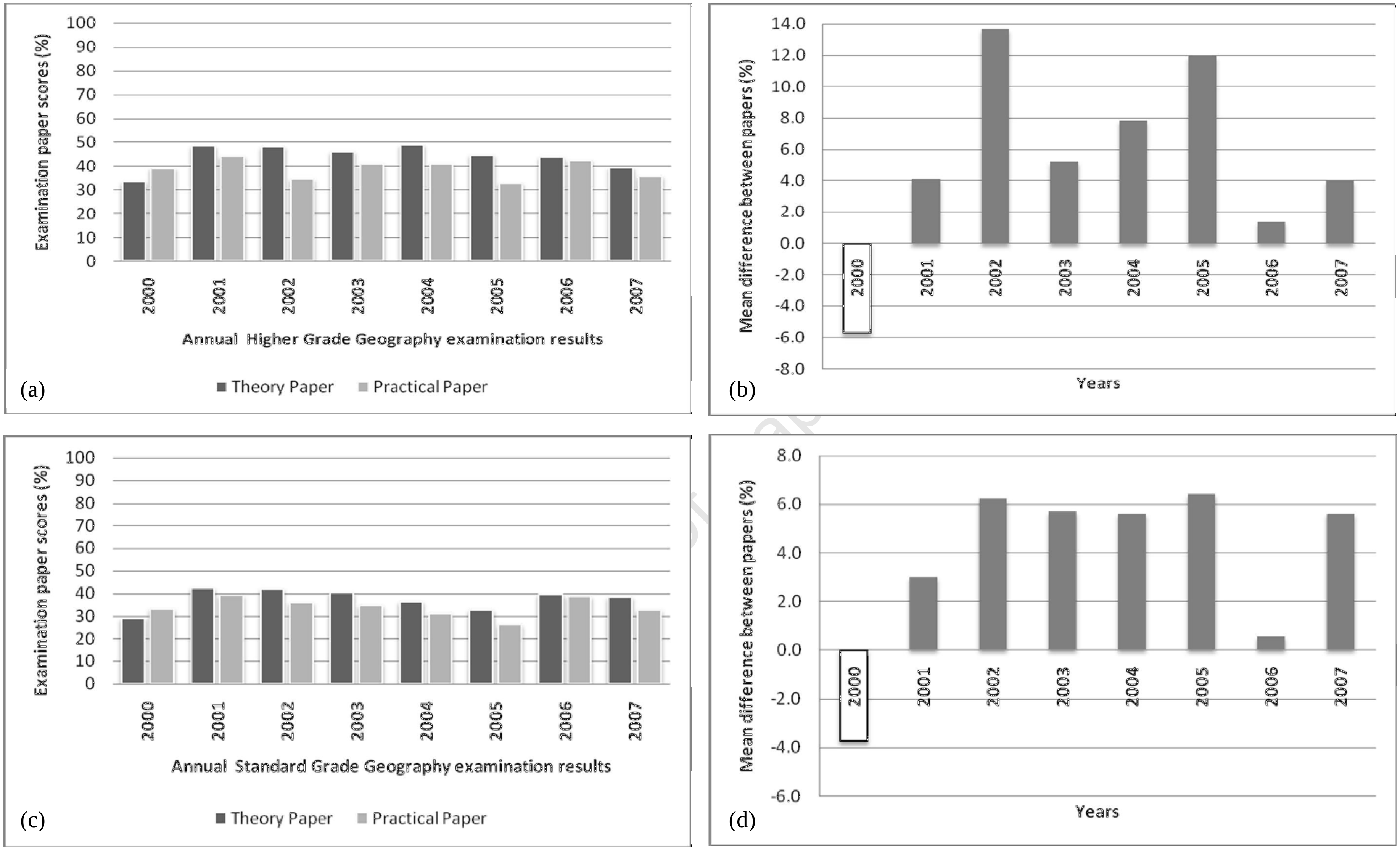


Figure A1.2 Northern Cape Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 592 to 1 374). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 2 217 to 4 673). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

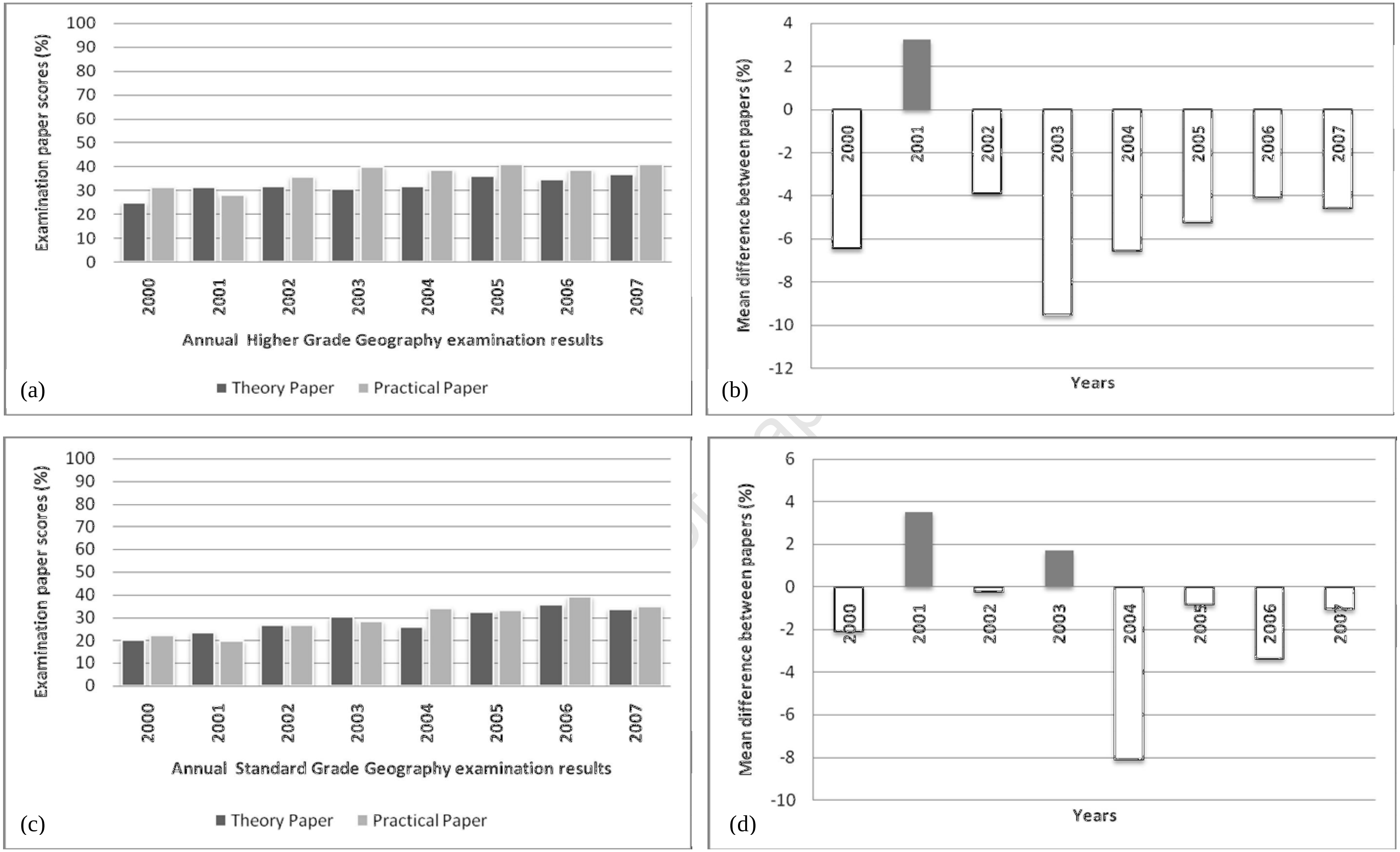


Figure A1.3 Free State Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 3 890 to 6 041). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 5 058 to 8 671). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

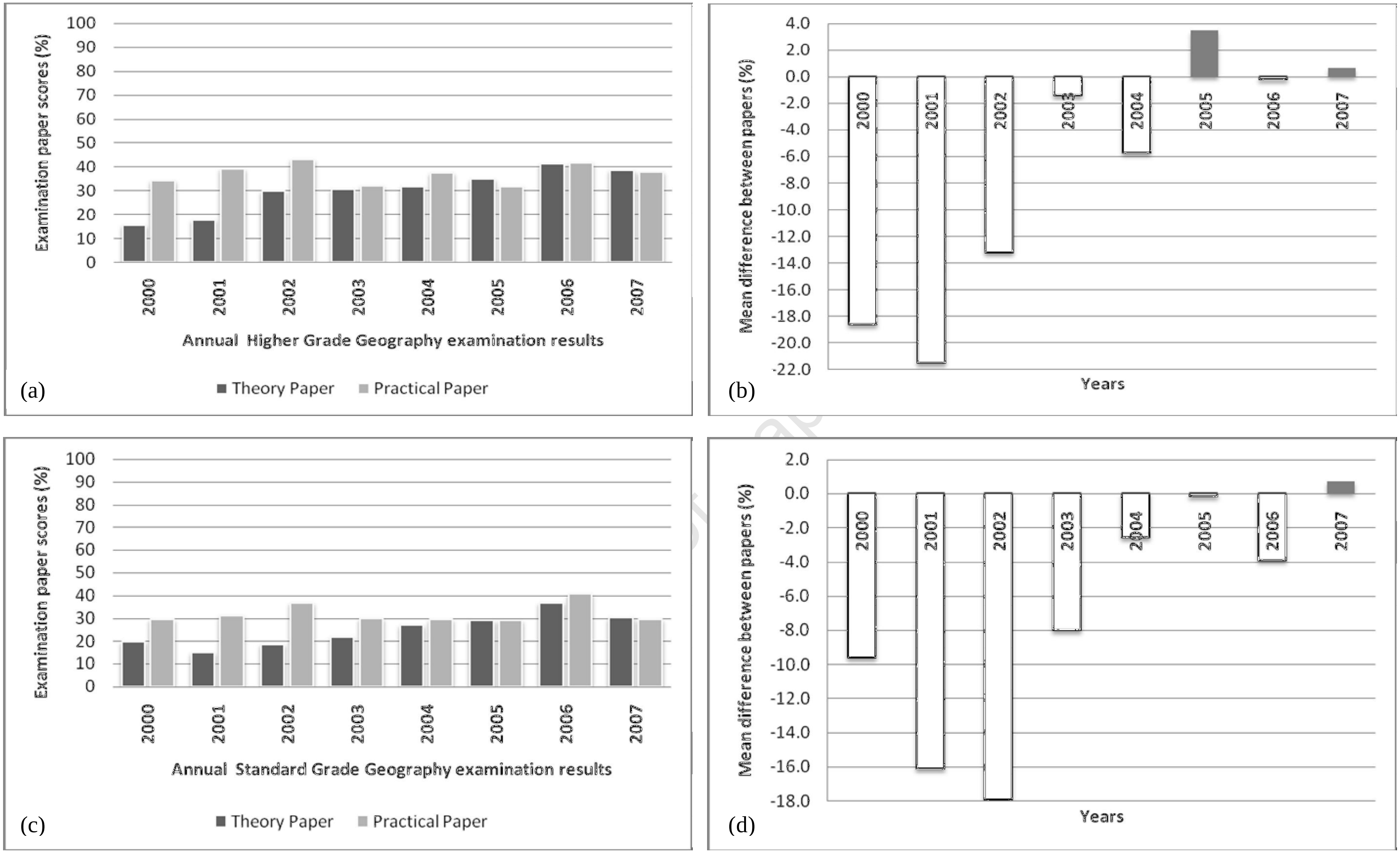


Figure A1.4 Eastern Cape Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 5 819 to 13 792). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 26 987 to 41 058). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

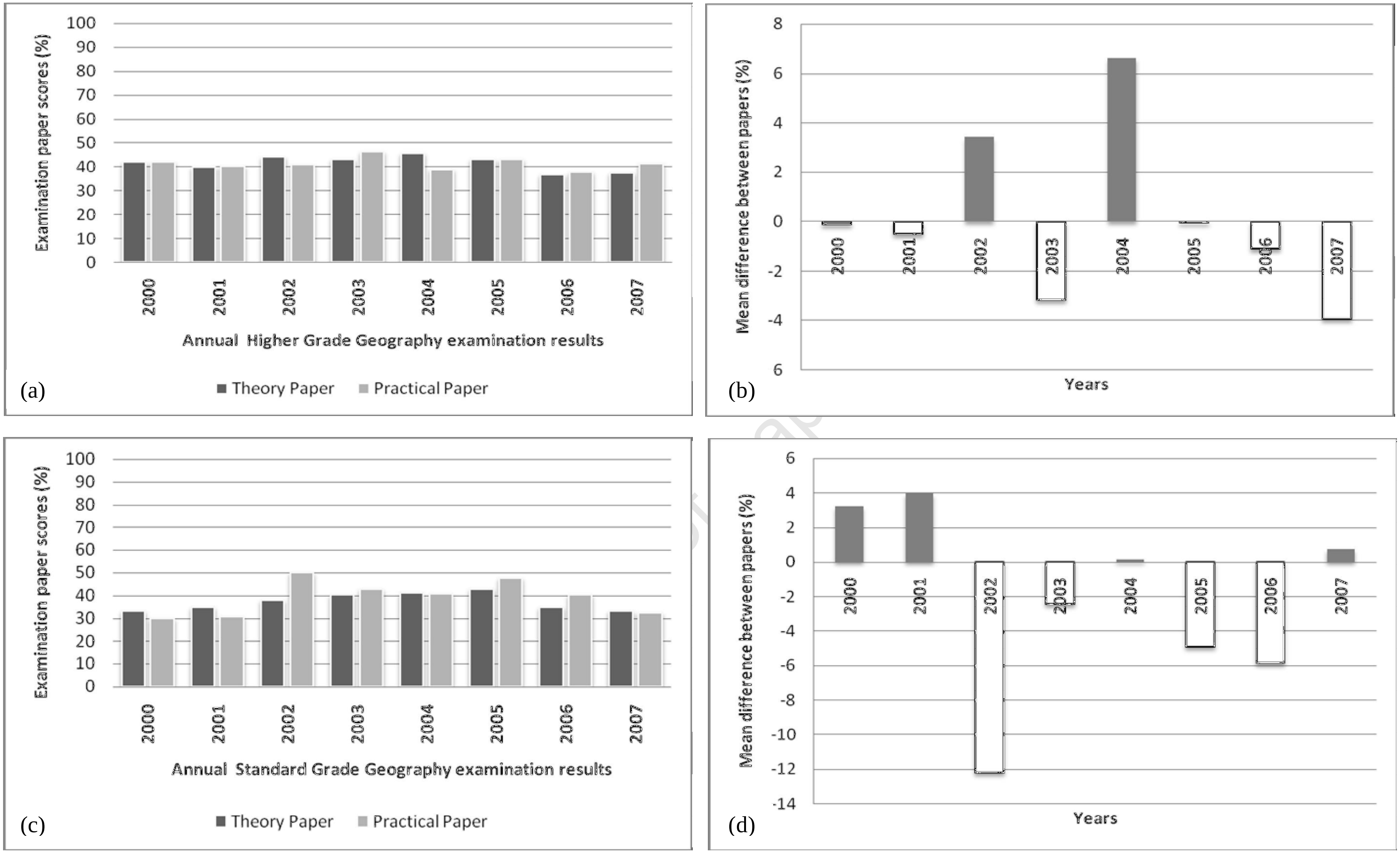


Figure A1.5 KwaZulu-Natal Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 16 143 to 34 824). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 24 224 to 38 882). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

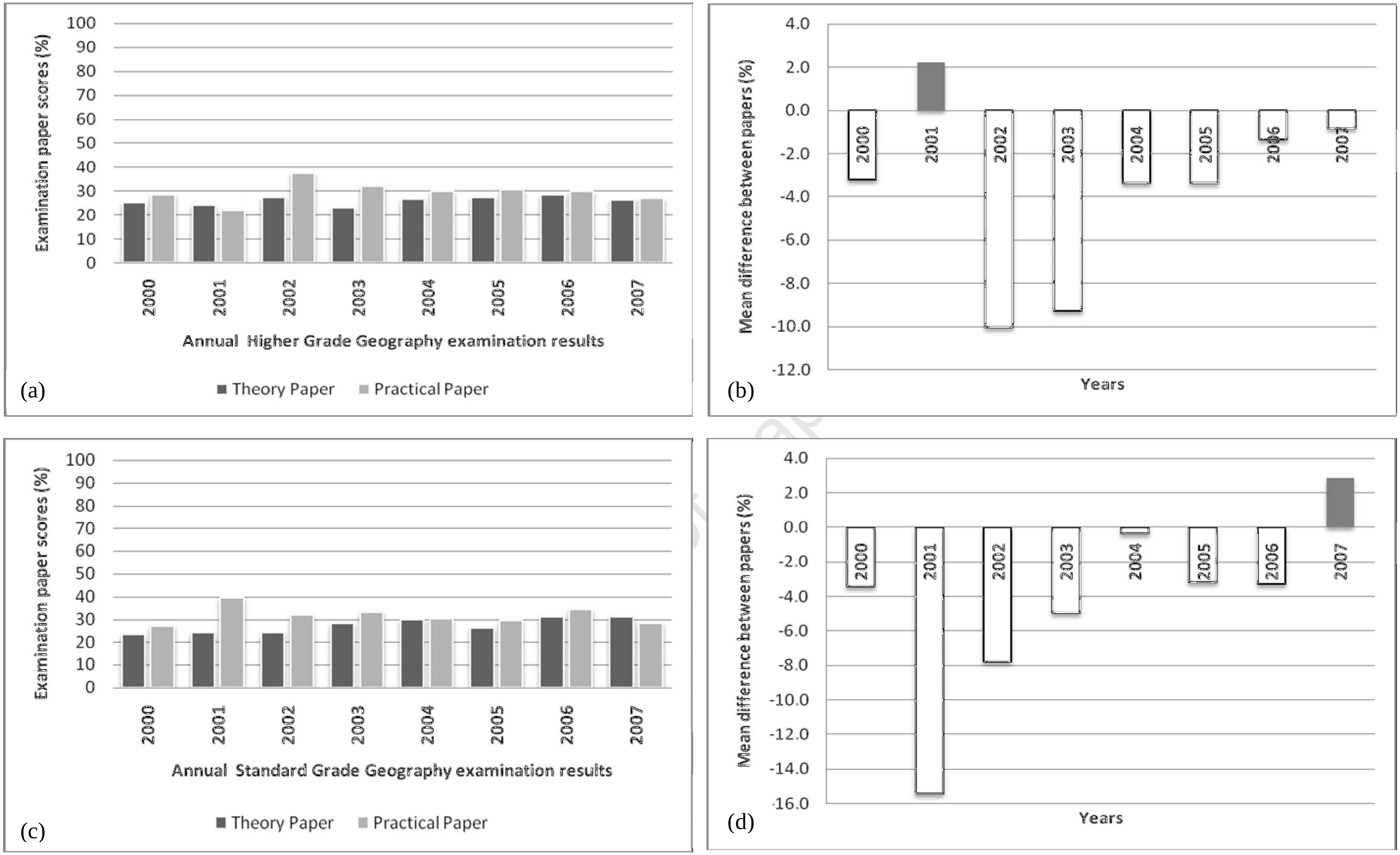


Figure A1.6 Mpumalanga Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 11 136 to 18 702). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 6 556 to 8 973). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

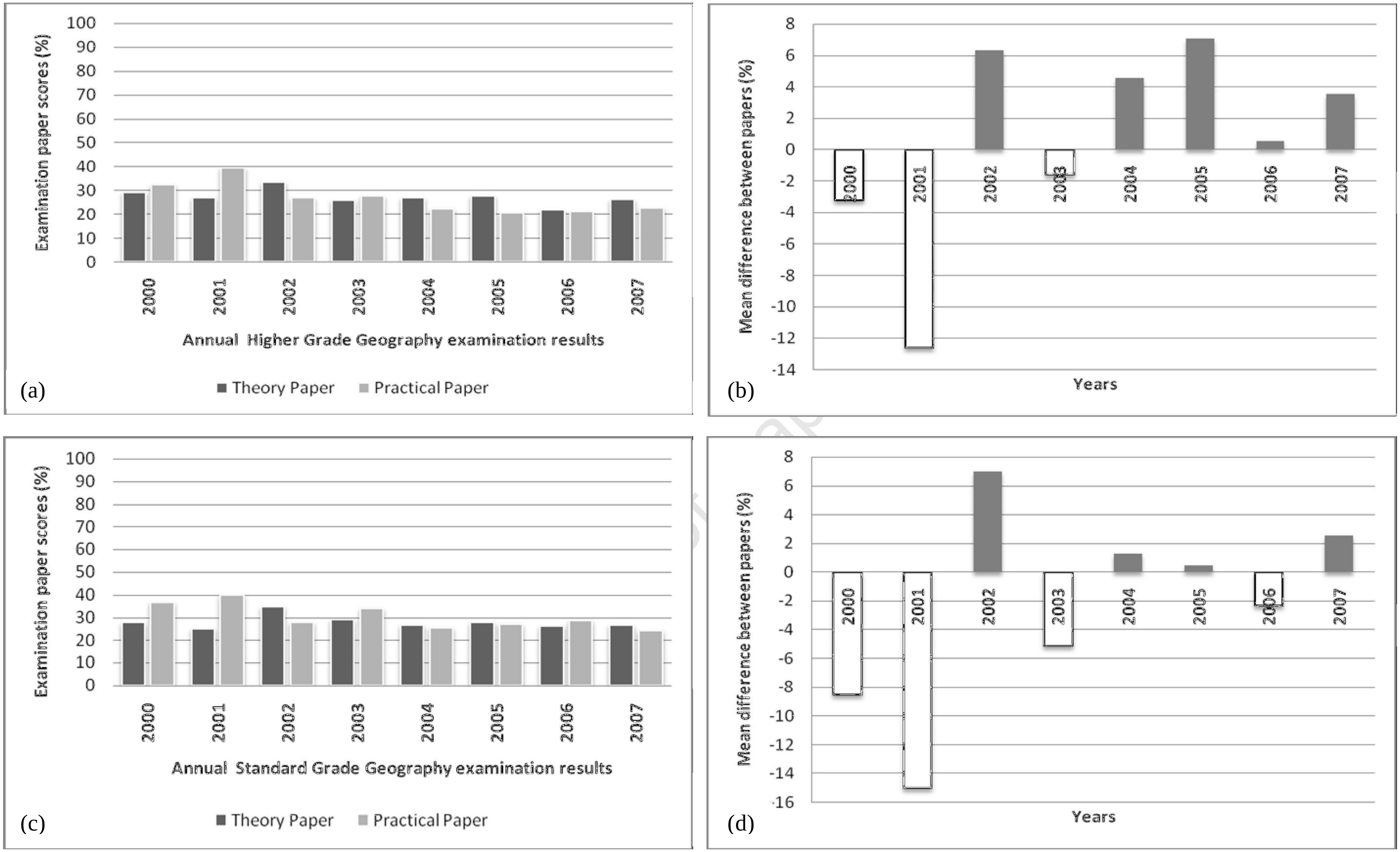


Figure A1.7 Limpopo Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 35 553 to 61 816). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 4 331 to 18 920). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

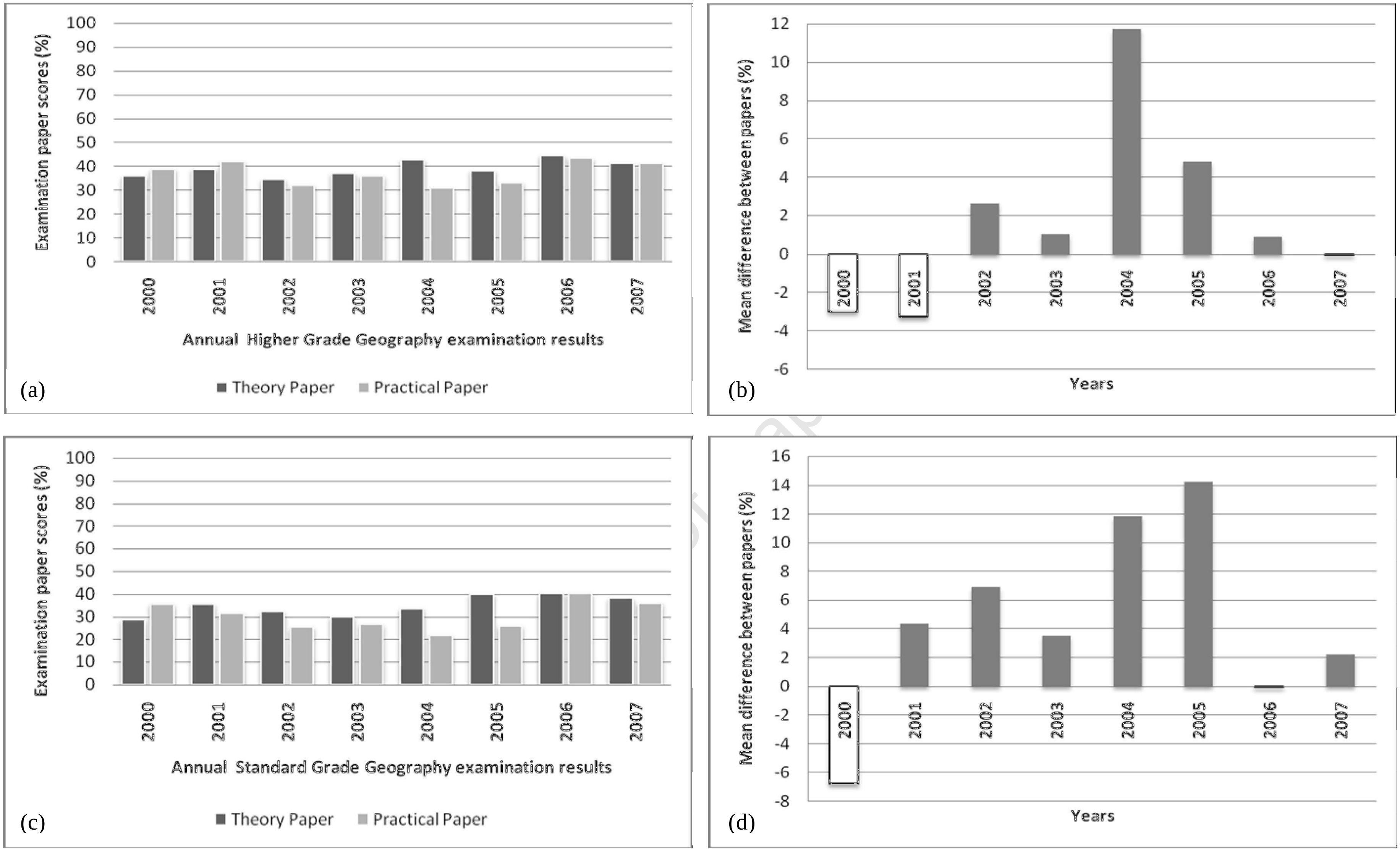


Figure A1.8 Gauteng Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 11 664 to 17 939). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 17 648 to 25 358). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

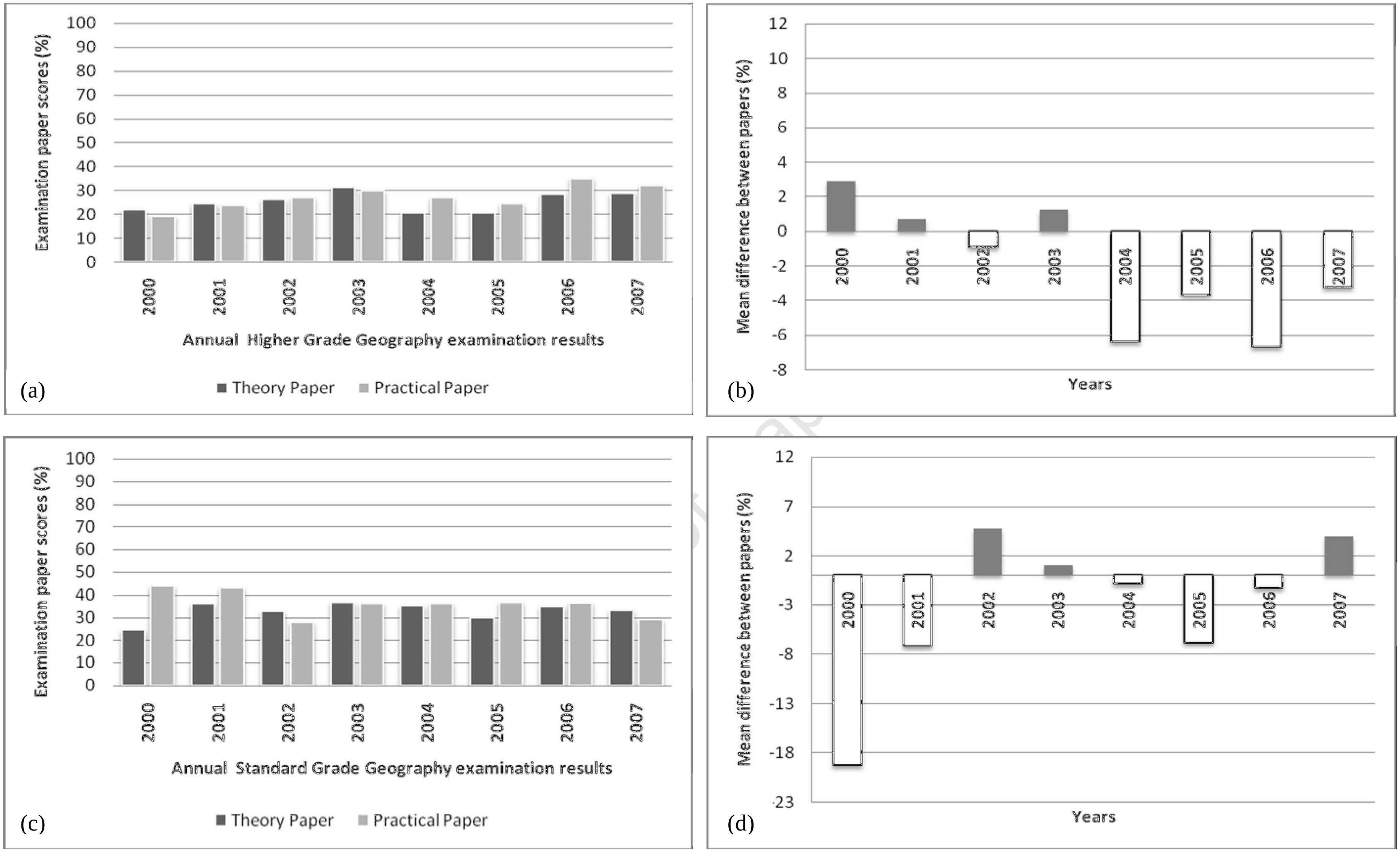


Figure A1.9 North West Geography matriculation examination results for the period 2000 to 2007. (a) Comparison of mean scores for Higher Grade papers (n ranges from 8 164 to 20 387). (b) Difference between mean scores (%) for Higher Grade Theory minus Practical paper. (c) Comparison of mean scores for Standard Grade papers (n ranges from 6 780 to 16 683). (d) Difference between mean scores (%) for Standard Grade Theory minus Practical paper.

Appendix 2.1

GIS IN EDUCATION PROJECTS

AT THE START OF THE NEW MILLENNIUM

(from Green, 2001)

Country	Organisation(s) responsible	Brief project / product description	Related technology and/or activities	Reported by
UK	Advisory Unit for Microtechnology in Education	AEGIS, introductory GIS software designed for schools (without full GIS functionality)	Mapping and database package designed to run on low-level computer systems commonly found in schools, supporting UK National Curriculum for Key Stages 2-4	AUME, 1990
USA	National Centre for Geographical Information Analysis (NCGIA)	GIS in Schools – Workshop Resource Packet	Started with teacher training initiatives, Resource Packet provided expertise and technology for schools	Palladino and Goodchild, 1993; Cadoux-Hudson and Heywood, 1993; Palladino and Zuyle, 1996
Oregon, USA	Coastal Studies and Technology Centre at Seaside High School, partnered with Columbia River Estuary Study Taskforce (CREST)	GIS based opportunity for staff and students to interact with community on local issues	Students taking high school science coursework are trained up to beginner level on ArcView under the guidance of professional scientists. GPS used for data entry, full range of peripherals available	Brown, 2001
Canada	PhD Associates	Geographic Analysis and Display System (GADS)	World statistics dataset and lesson on (i) Land use and settlement patterns and (ii) the ozone hole	NCGIA, 1993a and b
USA and UK	ESRI	CD-Rom – GIS for Schools and Libraries (in a number of versions)	ArcExplorer (geared down from ArcView) includes teacher resource pack and posters. Downloadable GIS software and datasets available on http://www.esri.com/	Green, 1991, 1992; Chaloner, 1992. Green 2001a
Ontario, Canada	TYDAC SPANS® and Nappanee District Secondary School	GIS skills project with teacher training module and curriculum toolkit	Secondary scholars learned a variety of GIS skills and worked with the community police association, regional conservation authorities and private businesses. Projects were feasible and practical and led to work placement for students.	SPANS, 1995; Sharpe and Best, 1999. Oliver, 2001
250 copies shipped world-wide	IDRISI (Clark Labs). integrated GIS and image processing package	GIS toolbox, originally DOS based now running on MS-Windows	Teacher training supplied, teacher's exercise pack released.	IDRISI 1996, 1998 http://clarklabs.org

GIS in education projects cont:-

Country	Organisation(s) responsible	Brief project / product description	Related technology and/or activities	Reported by
Powys County, Wales UK	Powys County Council, Ordnance Survey (OS) and the Association for Geographic Information	MapInfoTMGIS and teacher training supplied to all high schools.	Digital data for local tiles of selected OS maps, supplied for projects through Service Level Agreements to collaborate between Local Authorities, schools and Ordnance Survey	Smith, 1994; Gill and Roberts, 1998; Ordnance Survey, 1999 Rhind, 1993a and b
Northern Island	Ordnance Survey of Northern Island (OSNI)	Interactive, multimedia CD-Rom for schools	Uses ArcView and Lotus Cam, with GIS functionality, data input possible)	Galloway, 1997
Denmark	Aspen Global Change Institute	Using fieldwork and GIS for ground truthing remote sensing images		AGCI, 1992 Biilmann, 2001
Holgate School, Hucknall, Nottinghamshire UK	Association for Geographic Information and ESRI	GIS enabled fieldwork-based evaluation of green-belt	Project adapted for GIS after school won AGI/ESRI prize for proposed project	Walker, 2001

Appendix 3.1

DEPARTMENT: LAND AFFAIRS
REPUBLIC OF SOUTH AFRICA

PRP 2/2/1/4

Chief Directorate: Surveys and Mapping
Private Bag X10, Mowbray 7705 Tel : (021) 685 4070 Fax : (021) 689 1351
mapaware@sli.wcape.gov.za

MAPTRIX QUESTIONNAIRE

Dear School Principal

Please bring this to the attention of your Senior Geography Educator

According to information supplied to us*, your school was allocated one of the 2000 Kits containing *MapTrix: a Self-Instruction Programme for Topographic Map Reading* sponsored by the Department of Land Affairs. We are conducting a questionnaire survey to evaluate educator and learner attitudes to *MapTrix.* Educators are invited to collaborate in the further development of *MapTrix* for map and photo analysis and interpretation. Would you please make copies of this questionnaire if more than one geography educator at your school wishes to participate?

Please have the questionnaire(s) filled in and posted as soon as possible, or by 28 March 2002 at the latest, using the self-addressed free-post envelope. Your school will be providing valuable information and contributing to the development of learning materials for map use. As the only compulsory section in the matric geography examination, improvement in the marks for the map use question could lead to an overall improvement in geography standards.

Thank you for your help

The MapAware Project of the Chief Directorate: Surveys and Mapping

Please fill in the date before posting the questionnaire ………………………..

Please mark (ü or X) the yes/no spaces and answer the questions (put n/a if not applicable)

A. ACCESS TO *MAPTRIX* AND PERSONAL DETAILS OF RESPONDING EDUCATOR	**YES**	**NO**
1. Have you received the free *MapTrix Kit* allocated to your school?	….	….
2. If your answer is YES:		
a. How many months ago did the school receive *MapTrix*? ……………..*months*		
b. Have you used *MapTrix* with your geography learners yet?	….	….
c. If not yet used, would you like to use *MapTrix* as soon as possible?	….	….
d. Are you ever likely to use the *MapTrix Kit* at your school with your learners?	….	….
3. Had you received *MapTrix* information or training before getting this questionnaire?	….	….
4. If YES, please tick all the types of information or training received article in *The Teacher Newspaper* … / discussion with subject advisor … / workshop … / *MapTrix* Training Video … / *MapAware Brochure* ... / other …		
5. Has available information been passed on to other geography staff members?	….	….
6. For how many years have you been teaching geography? ……………………... *years*		
7. During your original teacher training, were you fully prepared for teaching map use?	….	….
8. Are you confident that your current topographic map use skills are adequate?	….	….
9. Do you believe a programme like *MapTrix* could improve your own map use skills?	….	….
10. Do you think the resources available at your school		
a. are adequate for the general needs of the school?	….	….
b. are adequate for teaching geography?	….	….

Please make suggestions or comments about the resources for teaching map use to your geography classes that **(a)** are **available** at your school and **(b)** you **need** but don't have.

(a) …………………………………………………………………………………………………

(b) …………………………………………………………………………………………………

*If no address was supplied, this was sent to each school with the above name. Please return questionnaire whether you have a *MapTrix Kit* or not.

IF YOU **DO NOT HAVE** A *MAPTRIX KIT* YET, YOU WILL NOT BE ABLE TO COMPLETE THE REST OF THE QUESTIONNAIRE. PLEASE POST THE QUESTIONNAIRE BACK TO US **NOW** WITH ONLY THE FRONT PAGE FILLED IN.

Thank you very much for your help.

(IF YOU HAVE AN UNUSED *MAPTRIX KIT*, PLEASE USE IT AS SOON AS POSSIBLE AND THEN COMPLETE THE QUESTIONNAIRE)

IF YOU **HAVE** USED A *MAPTRIX KIT* ALREADY AND COMPLETED THE PROGRAMME WITH AT LEAST ONE CLASS, PLEASE **CONTINUE**.

B. EDUCATOR'S EVALUATION OF THE ATTITUDE AND BEHAVIOUR OF LEARNERS WHEN USING *MAPTRIX*	**YES**	**NO**
1. In your experience of using *MapTrix,* did the **majority of learners** (± 60 %)		
a. find the procedure very complex and keep asking questions?	….	….
b. like to mark their own answers?	….	….
c. fail to understand at least 8 of the 10 questions in each exercise?	….	….
d. efficiently and independently follow the self-instruction procedure once they got used to it?	….	….
e. have difficulty finding the correct answers on the maps?	….	….
f. search through all the information (lessons and illustrations) for answers?	….	….
g. usually guess the answers without looking at the available information?	….	….
h. have difficulty using the playing card symbols to find the correct answer cards to match their work cards?	….	….
i. always mark their own work strictly according to the answer cards?	….	….
j. correctly fill in the bar graphs to monitor their own progress?	….	….
k. enjoy the *MapTrix* learning periods?	….	….
l. fail to complete the programme in the 12 learning periods recommended?	….	….
2. In your experience of using *MapTrix* as a teaching aid, did the **above average learners** (± top 20% of the class)		
a. become bored because they found *MapTrix* too easy?	….	….
b. willingly play the role of peer tutor to assist their classmates?	….	….
c. need to complete only 12 - 16 exercises in order to master* all four themes?	….	….
d. take 12 periods or more to finish the programme? If NO, approximately how many periods did they take? …………..…. *periods*	….	….
3. In your experience of using *MapTrix* as a teaching aid, did the **below average learners** (± bottom 20% of the class)		
a. become frustrated and therefore fail to complete the programme because they found *MapTrix* too difficult? If YES how many learners in the class failed to complete? …………………..…	….	….
b. feel encouraged by their improvement due to repeated practice?	….	….
c. take much longer than 12 periods to complete the programme? If YES, approximately how many periods did they take? …………..… *periods*	….	….
d. eventually master* all four themes?	….	….
**** master = get 8 out of 10 answers correct for at least one exercise on each of the 12 lessons***		

Please ask your learners what they liked **(a) most** and **(b) least** about *MapTrix* and record the answers given most often in each case.

(a) ………..

(b) ………..

What was the main **(a) advantage** and **(b) disadvantage** of using the self-instruction method (encouraging learners to teach themselves using already prepared learning materials)?

(a) ………..

(b) ………..

C. FURTHER DEVELOPMENT OF THE *MAPTRIX* SELF-INSTRUCTION PROGRAMME	YES	NO
1. If *MapTrix* were available now as a computer-based learning programme, would there be facilities at your school for learners to use it?	….	….
2. In your opinion does *MapTrix* in its present form meet **all** the needs of Grade 12 learners aiming for high scores on the practical paper for matric geography?	….	….
3. Could a self-instruction programme for map and photo analysis and interpretation help Grade 12 learners develop higher order skills for the practical paper?	….	….
4. Would you like to participate in the development of an advanced version of *MapTrix* to meet the needs of Grade 12 learners? *(Please see the end of the questionnaire.)*	….	….

D. EDUCATOR'S EVALUATION OF THE *MAPTRIX* PROGRAMME AND PROCEDURES

1. How many classes have you taught using *MapTrix*? …………………………………………… *class(es)*
2. What Grade(s) were the learners in? *Grade(s)* ……………………………………………………
3. How many learners were in the class(es)? (*numbers*) ……………………………………………
4. In your opinion, for which Grade is *MapTrix* most suitable? *Grade* ……………………………
5. The average length of geography periods at your school is …………………………… *minutes.*
6. What is the mother tongue of the majority of your learners? ……………………………………
7. What language(s) do you use for teaching/instruction? …………………………………………
8. What is the language of your geography matric examination paper? …………………………

	YES	NO
9. During the PREPARATION PHASE of the *MapTrix* programme was your local 1:50 000 topographic map sheet on display for the learners?	….	….
a. If YES, did the majority of learners show an interest in their local map sheet?	….	….
b. If YES could learners identify the familiar features of their environment?	….	….
c. If YES did the local map improve the learners' attitude to map reading?	….	….
d. Have you done any fieldwork with your learners, using your local map?	….	….
10. During the INTRODUCTION PHASE of the *MapTrix* programme, did you feel		
a. that the *MapTrix Educator's Guide* provided full and clear instructions?	….	….
b. anxious because the first few periods seemed a bit disorganised?	….	….
c. you could (or did) implement *MapTrix* effectively without the training *Video**?	….	….
11. During the ADMINISTRATION PHASE of *MapTrix,* did you find that		
a. the majority of learners' map reading skills improved while using *MapTrix*?	….	….
b. you were too busy with administration to help your below-average learners?	….	….
c. absentee or slow learners were unwilling to use MapTrix in their own time to catch up when they fell behind the rest of the class?	….	….
d. you had to impose discipline in the classroom more often than usual?	….	….
e. learners' comprehension of basic geography concepts was improved?	….	….
f. *MapTrix* could be used under the supervision of any responsible adult?	….	….
g. *MapTrix* improved the ability of below-average, senior-grade learners?	….	….
h. you would have preferred to mark the answers yourself?	….	….
i. your attitude to teaching map reading improved while using the programme?	….	….
j. *MapTrix* met the need for outcomes based support material for topographic map reading?	….	….
12. If you continue to teach geography, will you use *MapTrix* with your classes again?	….	….
13. Do you feel that *MapTrix* is a less efficient method of improving map reading than other methods you have tried?	….	….
If YES, please name the method you prefer ……………………………………………………		
14. Will you discourage other geography educators from using *MapTrix*?	….	….
15. Could *MapTrix* be used as extension material for fast learners in lower grades?	….	….
16. Would you recommend that your school purchase more *MapTrix Kits*?	….	….
17. If you use *MapTrix* in the future, will you administer the programme and procedures differently from those suggested in the *Educator's Guide*?	….	….
If YES, what would you do differently to improve the administration? ……………………………………………………………………………………………		
18. Would you prefer to use *MapTrix* in textbook format (despite the high cost)? If YES, would you like to use it for yourself ... / your learners ... / both ... (please tick)	….	….

MapTrix Video: see information in the accompanying green MapAware Brochure

E. EDUCATOR'S EVALUATION OF EXISTING *MAPTRIX* COMPONENTS	YES	NO
1. Do you think that the work cards are very flimsy and get damaged too easily?	….	….
2. Was it convenient to cut out the answer cards before using MapTrix?	….	….
If NO, please explain why: …………………………………………………………………….		
3. Are there too few work cards in the *Kit* to keep **all** the learners in the class busy?	….	….
4. Are there enough work cards on each topic (Landscape, Transport etc)?	….	….
If NO, which topic(s) need(s) more work cards		
5. Do you agree that the poster is of little help and should be left out of the *Kit*?	….	….
6. Do the Learner's Booklets provide		
a. enough information to guide learners through the programme?	….	….
b. too little space for learners to write down the answers?	….	….
7. Do the photographs help learners to understand the map symbol explanations?	….	….
8. Are the lesson texts clear and easy to understand?	….	….
If NO, please indicate the lesson(s) that is (are) unclear and why. ………………………………………………………………………………………		
9. Should some or all of *MapTrix* be translated to meet the needs of your learners? If YES, please indicate **(a)** the preferred language and **(b)** name the component(s) that you think should be translated.	….	….
(a) .... **(b)**		

The time you have taken to evaluate *MapTrix* is greatly appreciated. Your feedback will help improve possible future editions. If you would like to remain anonymous and you have no desire to help write exercises to develop advanced map use skills, please post off the questionnaire now.

Thank you so much

YOU ARE INVITED TO COLLABORATE IN THE DEVELOPMENT OF LEARNING MATERIALS FOR MAP AND PHOTO ANALYSIS AND INTERPRETATION

The proposed companion Kit for *MapTrix*, provisionally named *MapTrix 2*, will develop advanced map use skills, using the 52 maps on the existing large (A3) work cards. To be placed on top of these, 52 smaller (A4) work cards will each have an exercise with questions plus additional maps and/or photographs on one side and an illustrated lesson on the back. There will also be new answer cards and learner's booklets.

Your participation will benefit the research and development of *MapTrix 2* by providing:

- 'hands-on' ideas and inputs from experts who understand the needs in senior geography classrooms
- local knowledge of areas in, near, or similar to the places shown on the *MapTrix* map extracts.

You will benefit from:

- acknowledgement of your name and the name of your school in all research reports and/or publications
- the small gratuity to be paid per question and answer that can be used, if the work is published
- the chance to receive one of ten free copies of *MapTrix 2* (available on condition that it is published).

What you need to do if you would like to collaborate in the development of MapTrix 2:

Fill in the references (suits, plus names or numbers) of 3 *MapTrix* work cards for which you would like to develop advanced exercises. Fill in your name and address below and return the questionnaire as soon as possible. Once all nominations have been received (deadline date is 28 March 2002), you will be allocated one of your chosen work cards. The necessary guidelines such as theme, topic, provisional lesson text, question and answer length, will be provided and additional maps and photographs will be supplied, as necessary. Nominations from experienced geography educators living in or near the areas depicted on the *MapTrix* map extracts, will be given preference.

1st choice:	2nd choice:	3rd choice:
Name: tel/cell: fax:	Preferred address: email address:	

Appendix 3.2

RATING SCORES

A3.2.1. LEARNER ATTITUDE RATING SCORE

(Items used to test educators' perceptions of learner attitudes to *MapTrix*)

No.	Question	Reply	Total	%
B. 1.	In your experience of using *MapTrix* did the **majority of learners**			
b.	• like to mark their own answers?	YES	82	89.0
c.	• fail to understand at least 8 of the 10 questions in each exercise?	NO	65	70.3
k.	• enjoy the *MapTrix* learning periods?	YES	88	95.2
B. 2.	In your experience of using *MapTrix* as a teaching aid, did the **above average learners**			
a.	• become bored because they found *MapTrix* too easy?	NO	77	83.3
b.	• willingly play the role of peer tutor to assist their classmates?	YES	78	84.3
B. 3.	In your experience of using *MapTrix* as a teaching aid, did the **below average learners**			
a.	• become frustrated and therefore fail to complete the programme because they found *MapTrix* too difficult?	NO	68	73.9
b.	• feel encouraged by their improvement due to repeated practice?	YES	77	83.3

A3.2.2 LEARNER BEHAVIOUR RATING SCORE

(Items used to test educators' perceptions of learner behaviour while using *MapTrix*)

No.	Question	Reply	Total	%
B. 1.	In your experience of using *MapTrix* as a teaching aid, did the **majority of learners**			
a.	• find the procedure very complex and keep asking questions?	NO	48	52.1
d.	• efficiently and independently follow the self-instruction procedure once they got used to it?	YES	76	82.6
e.	• have difficulty finding the correct answers on the maps?	NO	64	69.6
f.	• search through all the information (lessons and illustrations) for answers?	YES	68	73.9
g.	• usually guess the answers without looking at the available information?	NO	61	66.3
h.	• have difficulty using the playing card symbols to find the correct answer cards to match their work cards?	NO	73	79.3
i.	• always mark their own work strictly according to the answer cards?	YES	70	76.1
j.	• correctly fill in the bar graphs to monitor their own progress?	YES	55	59.8
l.	• fail to complete the programme in the 12 learning periods recommended?	NO	45	48.9
B. 2.	In your experience of using *MapTrix* as a teaching aid, did the **above average learners**			
c.	• need to complete only 12 - 16 exercises in order to master all four themes?	YES	53	57.6
d.	• take 12 periods or more to finish the programme?	NO	25	27.2
B. 3.	In your experience of using *MapTrix* as a teaching aid, did the **below average learners**			
c.	• take much longer than 12 periods to complete the programme?	NO	33	35.9
d.	• eventually master all four themes?	YES	50	54.3

A3.2.3 EDUCATOR ATTITUDE RATING SCORE

(Rating educators' attitude to *MapTrix)*

No.	Question	Reply	Total	%
D. 10.	During the INTRODUCTION PHASE of the *MapTrix* programme, did you feel			
a.	• that the *MapTrix Educator's Guide* provided full and clear instructions?	YES	81	88.0
b.	• anxious because the first few periods seemed a bit disorganised?	NO	45	48.9
D. 11.	During the ADMINISTRATION PHASE of *MapTrix,* did you find that			
a.	• the majority of learners' map reading skills improved while using *MapTrix*?	YES	86	93.5
e.	• learners' comprehension of basic geography concepts was improved?	YES	86	93.5
f.	• *MapTrix* could be used under the supervision of any responsible adult?	YES	68	73.9
g.	• *MapTrix* improved the ability of below-average, senior-grade learners?	YES	81	88.0
h.	• You would have preferred to mark the answers yourself?	NO	56	60.9
i.	• Your attitude to teaching map reading improved while using the programme?	YES	84	91.3
j.	• *MapTrix* met the need for outcomes based support material for topographic map reading?	YES	84	91.3
D. 13.	Do you feel that *MapTrix* is a less efficient method of improving map reading than other methods you have tried?	NO	86	93.5
D. 15.	Could *MapTrix* be used as extension material for fast learners in lower grades?	YES	86	93.5
D. 18.	Would you prefer *MapTrix* in textbook format (despite the high cost)?	NO	32	34.8
E. 1.	Do you think the work cards are flimsy and get damaged too easily?	NO	49	53.0
E. 3.	Are there too few work cards in the *Kit* to keep **all** the learners in the class busy?	NO	41	44.6

A3.2.4 EDUCATOR BEHAVIOUR RATING SCORE

(Rating educators' behaviour in response to using *MapTrix)*

No.	Question	Reply	Total	%
D. 11.	During the ADMINISTRATION PHASE of *MapTrix,* did you find that			
b.	• you were too busy with administration to help your below-average learners?	NO	49	53.0
d.	• you had to impose discipline in the classroom more often than usual?	NO	63	68.5
D. 12.	If you continue to teach geography, will you use *MapTrix* with your classes again?	YES	89	96.7
D. 14.	Will you discourage other geography educators from using *MapTrix*?	NO	86	93.5
D. 16.	Would you recommend that your school purchase more *MapTrix Kits*?	YES	79	85.9
D. 17.	If you use *MapTrix* in the future, will you administer the programme and procedures differently from those suggested?	NO	71	77.2

Cape Town

3318CD Map Extract 33°53'30"S; 18°23'30"E

Latest edition 1998

For thousands of years hunters and gatherers from the interior of Southern Africa visited the shores of Table Bay. Travellers passed Cape Point by ship but left no evidence of permanent settlement. The first building was started by Jan van Riebeek in 1652 when he arrived to start a refreshment station for the ships of the Dutch East India Company. He built the star-shaped fort, *Die Kasteel* (E5), to protect the early settlers. The original Cape Town harbour consisted of the Alfred Basin (B4); the Victoria Basin was added later. This area, the Waterfront, is now a popular tourist attraction. The new harbour has two large docks which handle import and export trade. Tourism is one economic activity in this city; others include manufacturing, trade, transport and a range of administration, medical and education services.

1 Name the hospital in **F9** where the world's first heart transplant operation was performed.

2 There are two circles on the main road in **D5**. Whose statue has been erected as a memorial in one of the circles?

3 As a city grows surrounding farmland becomes built-up area. Name the suburb (**E2** and **E3**) that was laid out on part of the original farm established by Jan van Riebeek to supply passing ships with fresh fruit and vegetables.

4 Name the type of natural feature in **K3**, **J1** and **H3** where the early hunter/gatherers, who visited this area, may have taken shelter.

5 Name the transport link between the Upper Station (**H2**) and the Lower Station (**G2**) on Table Mountain (*Tafelberg*), which modern day visitors may use when visiting the city.

6 The Mouille Point lighthouse (**B2**) was erected to warn passing ships. Name (a) the conventional symbol used instead of a blue line to mark the coastline and name (b) two of the ships that were unable to avoid the danger.

7 To gain city status a town must offer many high order services including education beyond secondary school. From **H9**, **F6**, **K9** and **E5** give three tertiary education institutions found in the city of Cape Town.

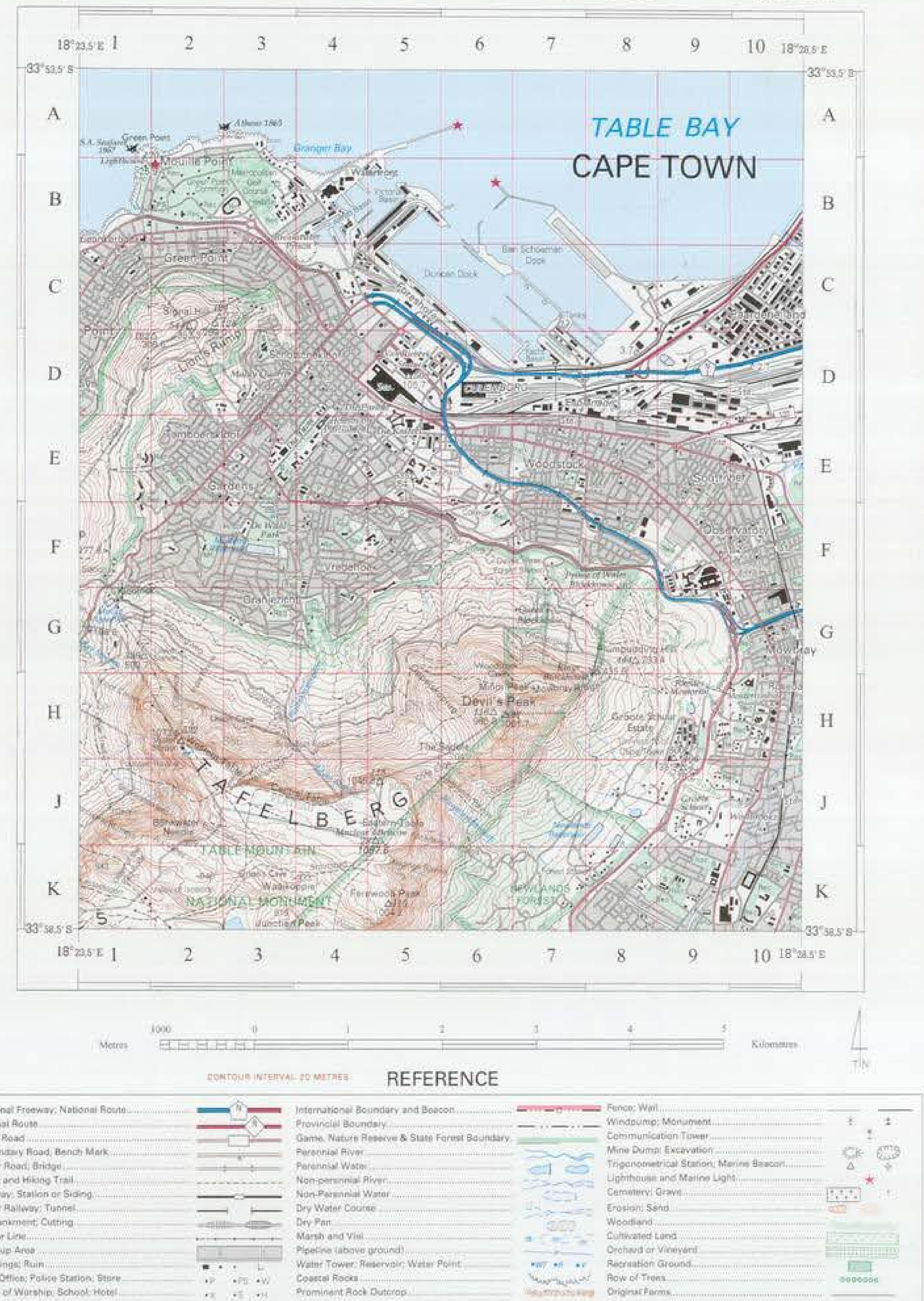
8 This map extract covers only a small part of Cape Town. The city stretches many kilometres to the north-east, east and south. All the residents need a permanent supply of fresh water. Name any two of the large reservoirs, built to store perennial water, on the mountain slopes above the city.

9 Railway trucks loaded with goods from the ships in Duncan Dock have to be sorted out and linked to engines to go to their destinations. Name the railway feature where this is done between the freeway and the main railway in **D6** and **D7**.

10 You are standing at the highest trigonometric station on Devil's Peak (named in **H6**), looking out over this beautiful city and surrounding mountains. How many metres below you is the yacht basin (**D7**)?

MapTrix

Ace EXTRACT FROM CAPE TOWN 3318 CD 1:50 000



Urban settlement
Large cities

An **URBAN SETTLEMENT** is a town or city where many people have come to live (settle). Urban settlements are easy to recognise on a topographic map because there are many different conventional signs concentrated in one part of the map. This part is shaded grey to show a built-up area. The conventional signs used for urban settlements show the buildings associated with the kind of work people do to make a living and where their families live, go to school and play sport.

By the time you have mastered this topic you will be able to:
- identify different urban features on the topographic map and
- describe what different parts of an urban settlement are like.

LARGE CITIES are places where thousands of people live. The type of work they do includes a variety of economic activities. Manufacturing industries are secondary economic activities; they process or make new things out of the raw materials produced by primary economic activities such as fishing, farming, forestry or mining. All forms of trade and services are tertiary economic activities. There are different land use zones in a city for these activities but the largest area is taken up by residential suburbs.

BUILT-UP AREAS are the grey areas on topographic maps which show where buildings have been built close together. Built-up areas are divided up by **streets** into blocks of stands. The streets between the blocks form patterns which help us understand what the area looks like. Only three street patterns are described here, there are many others!

Street patterns can be described as:
- radial (streets radiate outward from a central point like the spokes of a wheel),
- grid (streets cross at right angles to form evenly sized blocks) or
- irregular (streets wind between blocks of different shapes and sizes).

RESIDENTIAL AREAS are the parts of an urban area where people live.

LOW INCOME RESIDENTIAL AREAS are where most urban dwellers live. The grid street pattern with either small square blocks or long narrow blocks of *very small stands* is often used. Because the stands (yards) and houses are small, there are many people living close together, hence the term high density housing. Many **schools, churches** possibly a **clinic** are shown. In the past, low income residential areas were placed far from the centre of the town. Informal settlements have grown rapidly around the edges of many cities, often faster than the maps of the cities can be updated! Old blocks of flats on small stands close to the CBD of large cities also provide high density housing for low income families.

MIDDLE INCOME RESIDENTIAL AREAS are where people live who earn medium sized salaries. Some middle income earners stay in two or three storey flats which are on slightly larger stands just outside the CBD. By comparing the sizes of the street blocks in different parts of an urban area, we can usually identify the blocks of *medium sized stands* where people in the middle income bracket live. **Schools, churches** and a **suburban shopping centre** may be marked on the map as well as **recreation facilities**.

HIGH INCOME RESIDENTIAL AREAS are where people live who earn high salaries. They can afford *large stands* or pieces of ground so these street blocks are the largest in the urban area. They are usually far from the CBD, in attractive places beside **rivers** or along **ridges**. **Parks** and **golf courses** may be found here. The houses are far apart so these suburbs are called low density housing areas.

MARSHALLING YARD

A **marshalling yard** contains many railway tracks beside each other and is often found near a large railway station. Goods trucks are uncoupled from the train engine that pulled them into the marshalling yard. The trucks are moved and then coupled (linked) to different engines to take them to their destinations.

AERIAL CABLEWAY

An **aerial cableway** is a method of transporting people or goods up and down very steep mountain slopes. Strong steel cables are fixed at the top and bottom of the slope. A cable car or lift (like this one) hangs on one cable and another cable pulls it to the top or lowers it to the bottom of the slope.

MARINE LIGHT OR LIGHTHOUSE

Very bright **marine lights** are erected on the coast where there are dangers to ships. Sometimes the light is built into the top of a tall building called a **lighthouse**. During the night these lights flash on and off, guiding ships and boats into safe harbours and warning them to stay away from dangerous rocks or shallow water.

COASTLINE

The **coastline** is the line between the sea and the land. Bays and sandy beaches form a smooth or gently curved coastline. This is the line showing mean sea level, from where all heights are measured. Mean sea level is the average height of the sea surface calculated from long records of tidal variations.

MONUMENT

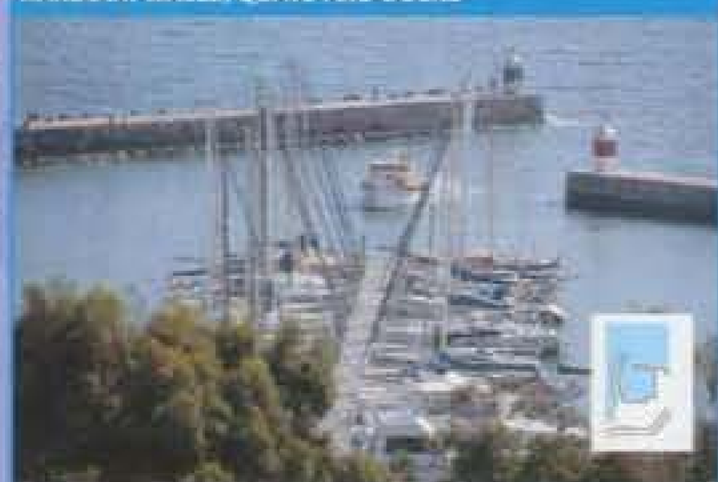
A **monument** is a building, statue, memorial or other structure of historical importance. When the site deserves to be remembered by the whole nation, it is declared a national monument.

(Monuments have been erected on most battlefields which are therefore no longer marked on maps with the symbol of the crossed swords.)

SHIPWRECK

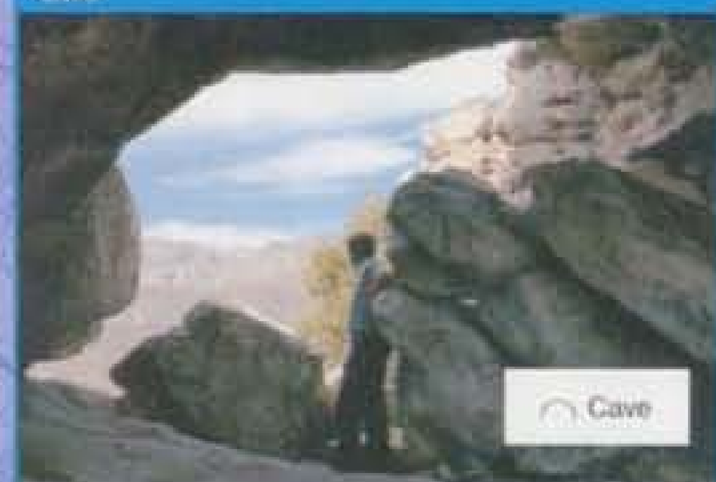
The place where a **shipwreck** has occurred is shown on the map as a warning to other ships. Ships which have sunk in deep water will not be visible but where a ship has run on to rocks (like this one), it can be seen for many years until the waves break it up completely.

HARBOUR WALLS, QUAYS AND DOCKS



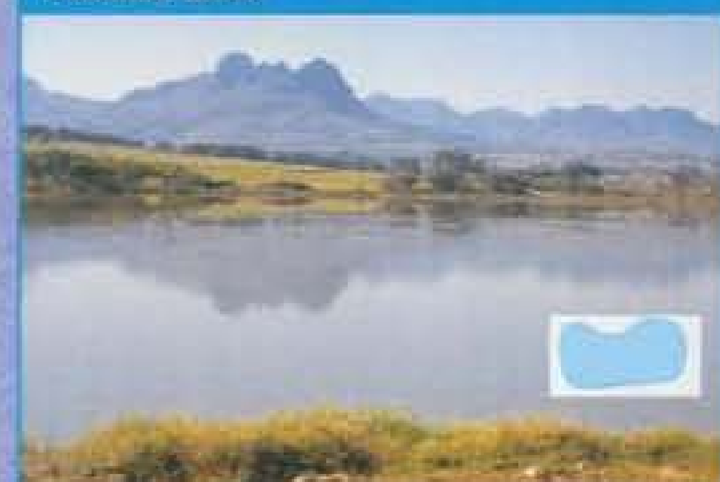
A **harbour** is a place of shelter where small boats and large ships can come alongside the coast safely. One or more breakwaters or strong **walls** are usually built up from the seabed to make a harbour. Ships are guided into the deep water of the **dock** inside the harbour and are moored (tied up) beside the **quay** to take on and off-load goods and passengers. A black line is used, instead of the blue coastline, to show the harbour construction.

CAVE



A **cave** (*grot*) is a natural, hollowed out space under the ground or in the side of a mountain that can be reached from the surface. Early hunter-gatherers sheltered or lived in caves which they sometimes decorated with rock paintings.

PERENNIAL WATER



Perennial water is permanent, just like the sea. The lake or pan where perennial water is found never dries up and the water can be used throughout the year. (See also dam.)

HOSPITAL OR CLINIC

There is no sign for a **hospital** or **clinic**. The word or its abbreviation is printed on the map. A clinic offers primary health care and is staffed by nurses and qualified sisters. At a hospital there is usually one or more doctors on duty at all times with the nursing staff.

MapTrix

JUTA

Appendix 4.2

RT100F Map Use Test

INSTRUCTIONS

Part A: Answer the 10 map reading questions on the *MapTrix* Work Card - Ace of Clubs (♣) which shows an extract from the Cape Town topographic map sheet 3318CD.

Part B: Answer any 5 of the following map analysis questions. You may need to use the aerial photograph of the campus which is on display.

You may leave when you are finished.

<u>NB: WRITE DOWN YOUR STARTING TIME AND YOUR FINISHING TIME.</u>

11. Name the kind of station you would find at 33°58'12"S; 18°27'0"E and name the area that it serves.

12. Along what true bearing would a helicopter pilot fly after collecting water from the middle of Newlands Reservoir (J8) to put out a fire at the top of Plumpudding Hill (G8)?

13. If you were walking along the contour path, heading northwest after crossing Platteklipstroom (H3), what contour would you be following?

14. How far, in metres, is Kings Block House (the building beside the trig. beacon in G8) from the end of the road to Rhodes Memorial (H9)?

15. What is the difference in altitude between the end of the access road to Rhodes Memorial (H9) and Kings Block House (G8) (use the trig. Beacon height)?

16. Calculate the gradient of the slope that visitors climb between the national monuments mentioned in Question 15.

17. To prevent further urban encroachment up the slopes of Table Mountain, a large area has been declared a national monument. Study the cross section provided which shows a profile of the area between the highest points on Devil's Peak (H6) and Signal Hill (C2). Give the letters of those sections that fall outside the conservation area.

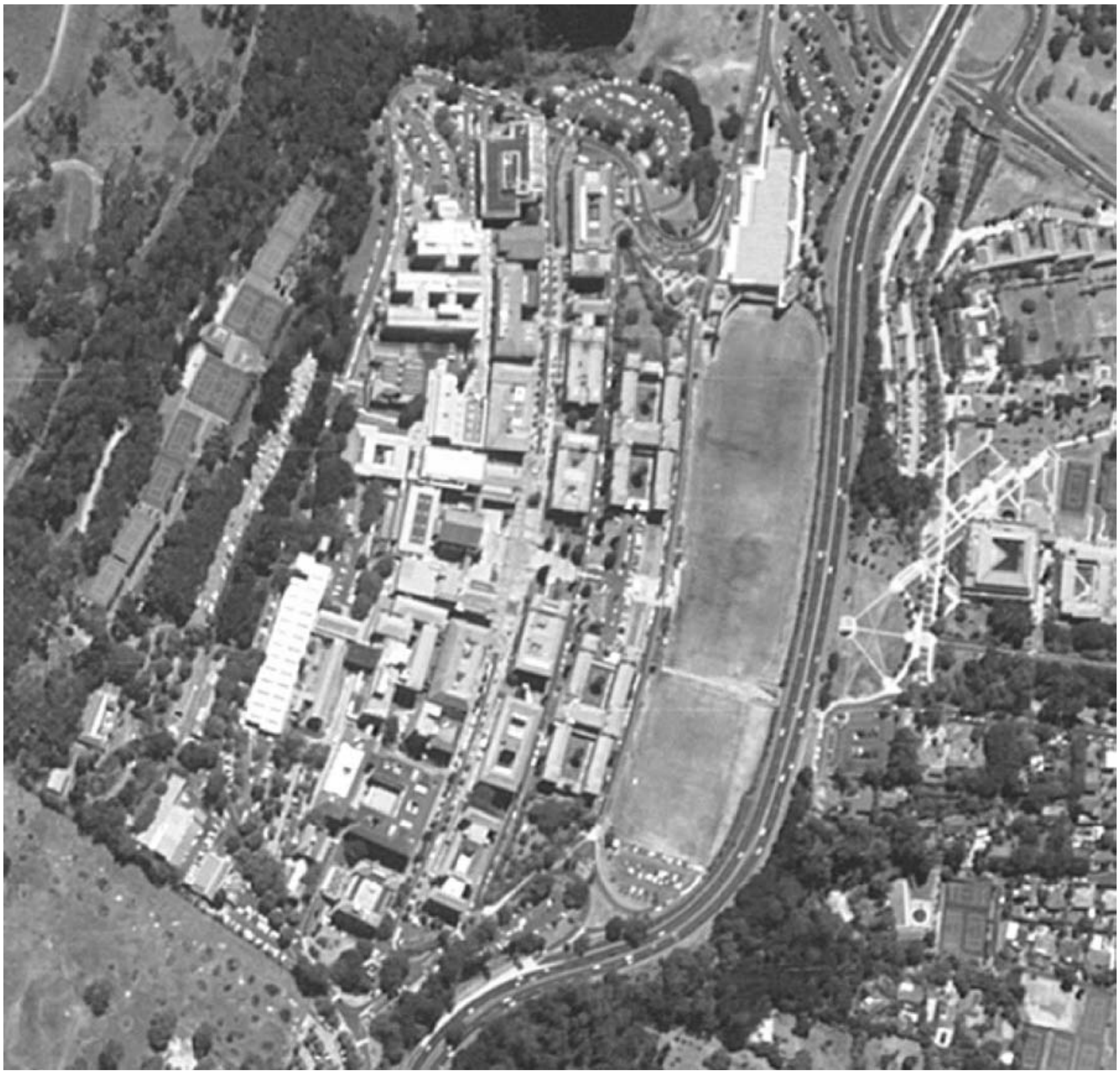
18. What distance would you cover if you walked the length of the rectangular recreation area below the University of Cape Town H9)?

19. Measure the length of the same recreation area (as in Question 18) on the vertical aerial photograph of the campus. Give the photo distance in cm.

20. Calculate the approximate scale of the vertical aerial photograph.

Appendix 4.3

Example of vertical aerial photograph of UCT upper campus (a similar image at a much larger scale was displayed on the wall of the test venue)



Appendix 5

DEFINING SPATIAL COMPETENCE QUESTIONNAIRE

Please answer Sections I and II using responses A, B or C in the empty blocks.
A = Very often (every day or alternate day), B = Quite often (once or twice a week), C = Seldom (once or twice a month)
(For products or tasks needed less often, please leave boxes empty.)

Section I. Please indicate the types and formats of spatial information that you use on a regular basis

Aerial photographs				Topographic maps (1:50 000)				Road maps				Orthophoto maps 1:10 000				National or regional maps				Property diagrams			
paper		digital		paper		digital		paper		digital		paper		digital		paper		digital		paper		digital	

Thematic maps (please fill in the types you use)	paper	digital
e.g. Climate maps		B

Please fill in any other types and/or formats of spatial information that you use regularly

Section II. Please indicate the tasks you perform regularly using spatial information (Fill in A, B or C beside the appropriate accuracy level.)

1. Locating features using		4. Describing absolute location		7. Calculating area		10. Visualising terrain		12.
1a. an alpha-numeric grid		4a. using alpha-numeric grid		7a. correct to 1 ha		10a. Integrating natural and constructed landscape		
1b. latitude and longitude		4b. latitude and longitude		7b. correct to 10 m²				
1c. survey co-ordinates		4c. survey co-ordinates		7c. correct to 1 m² or less		10b. + plus changes over time		
2. Describing relative location using		5. Estimating altitude		8. Identifying landforms -		11. Reproducing features		13.
2a. direction (8 cardinal points)		5a. correct to ± 10 m		8a. name features		11a. by sketching/copying at the same scale		
2b. bearing correct to ± 2°		5b. correct to ± 1 m		8b. describe slope form/aspect				
2c. bearing to 1° or less		5c. correct to < 1 m		8c. generate profiles		11b. at larger or smaller scales		
3. Calculating distance		6. Calculating/recording gradient		9. Identifying boundaries		Other tasks? Please list them in the last column ➔		14.
3a. correct to ± 10 m		6a. as a ratio (height:distance)		9a. regional/district boundaries				
3b. correct to ± 1 m		6b. as an angle of slope		9b. land use zones				
3c. correct to < 1 m		6c. as a trigonometric function		9c. property boundaries				

Section III. Please rate the difficulty level of the sub-tasks in Section II by writing the sub-task numbers in the boxes below

VERY EASY	EASY	MODERATELY DIFFICULT	VERY DIFFICULT
e.g. 15a		15b	15c
All school leavers with a GET certificate (Grade/year 9) should be able to perform these tasks	By the end of Grade 10 learners who have elected geography should be able to perform these tasks	Geography learners with an FET (grade/year 12) certificate should be able to perform these tasks	Competence in these tasks should be developed in the work place or through tertiary training
Elementary spatial competence	Basic spatial literacy competence	Intermediate spatial literacy competence	Advanced spatial literacy competence
No employment opportunities	Very limited employment opportunities	Good employment opportunities	Distinct advantages for employment

Section IV. Please review the proposed definition of spatial competence and approve, reject or amend as you think necessary, then tick (✓) the relevant block below the frame.

Proposed definition		
Spatial competence is the ability to • read with understanding spatial information about the natural and constructed environment from various sources including paper and digital maps and aerial photographs, • analyse that information and present results orally, verbally or mathematically, • visualise the landscape (including changes over time) from the interpretation of spatial information and • represent selected information graphically as required.		
approved ☐	rejected ☐	amended as above ☐

Section V. Participant details (no name is required; the results of this anonymous survey will be used for research purposes only)

Job title, position or line function	Level of qualification (please tick ✓ below box)							Type of employer (e.g. college, NMO)
	pre-matric	matric(M)	M+1	M+2	M+3	M+4	M++	

Thank you for your willingness to participate in this survey

Appendix 5

Appendix 6.1 (i)

Boundaries

♥

Odd Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	
1	Direction	
2	Position	
2	Bearing	
3	Height	
3	Distance and area	
4	Gradients	
4	Profiles	

Key Questions:

- Why is it important to be able to identify boundaries?
- What kinds of boundaries are there?
- How can boundaries be identified
- Which physical features can be used as boundaries ?
- What features are constructed to mark boundaries?
- How are watersheds used as boundaries?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skill (Learning Outcome 1) relative to boundaries, when they can:

- Distinguish between natural and constructed boundaries
- Recognise boundaries on a map and in their local area
- Explain the significance of cadastral/property boundaries
- Identify boundaries between different land uses

Appropriate resources:

- A lesson on boundaries (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. a property diagram, deed of sale, map extract at another scale, photographs, etc)

Instructions

Questions

*Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to **boundaries**.*

Question content could relate to:

- *Patterns and angles formed by boundary lines*
- *Patterns of bounded shapes (e.g. reserves or fields)*
- *Distinction between a natural boundary (e.g. a river or watershed) and a constructed boundary (e.g. a fence or road)*
- *Types of boundaries (e.g. national, original farm)*
- *Beacons, posts and other nodes along boundaries.*
- *Physical boundaries (e.g. a watershed around a drainage basin).*

Answers

- *All answers to be one to five words or numbers.*
- *For two questions at least, answers to be names of types of boundaries*
- *For two questions at least, select names of bounded areas (e.g. original farms).*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer used unaltered in the publication of MapTrix 2 will be remunerated. Please add your name and contact details at the end of the worksheet.

Direction

♣

Odd Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	
1	Direction	
2	Position	
2	Bearing	
3	Height	
3	Distance and area	
4	Gradients	
4	Profiles	

Key Questions:

- Why is it important to be able to name directions?
- In what situations is it important to understand, give and name directions correctly?
- How can direction be used to describe location?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skills (Learning Outcome 1) relative to direction when they can:

- Distinguish between relative and absolute location
- Relate direction on a map to compass direction
- Explain the significance of the north arrow
- Use the framework of lines of latitude and longitude on a map to identify direction
- Distinguish between direction from and direction to
- Name the direction of 16 cardinal points correctly

Appropriate resources:

- A lesson on direction (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. a road map of the same area, diagram of a wind rose, illustration of a compass rose, actual compass, cartoon, etc)

Instructions

Questions

*Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to **direction**.*

Question content could relate to:

- *direction of travel (by road, rail and air), river flow, wind or any other moving phenomenon*
- *position of features relative to other features*
- *position of dams relative to direction of river flow*
- *descriptions of relative position*

Answers

- *All answers to be one to five words or numbers.*
- *For two questions, answers to be one of the 4 cardinal points.*
- *For two questions, select answers from one of the 8 cardinal points.*
- *Relate the rest of the questions and answers to all 16 cardinal points.*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer that are used in their original form in the publication of MapTrix 2 will be remunerated. Please add your name, address and phone number at the end of the worksheet.

Position

♥

Even Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	ü
1	Direction	ü
2	Position	
2	Bearing	
3	Height	
3	Distance and area	
4	Gradients	
4	Profiles	

N.B. Only spatial analysis skills ticked off above can be assumed when formulating questions

Key Questions:

- Why is it important to be able to describe position?
- How can features be located on a map?
- What are the different ways of describing position?
- How is position related to latitude and longitude?
- What is a GPS (Geographic Positioning System)?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skills (Learning Outcome 1) relative to position when they can:

- Describe the position of features on medium scale maps (1:50 000) correct to the nearest 10"
- Describe the position of features on large scale maps (1:10 000) correct to the nearest 5"
- Find features on maps using co-ordinates

Appropriate resources:

- A lesson on position including latitude and longitude (still to be drafted)
- Topographic and matching orthopoto map extracts

Please write down any other resource that you would like to recommend (e.g. extract of a map at a different scale, diagram, photographs, etc)

Instructions

Questions

Please formulate 7 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to ***position****. (Note: The other 3 questions will be based on an accompanying orthophoto map extract)*

Question content could relate to:

- *The co-ordinates of places identified by dot symbols*
- *The co-ordinates of ends or bends in features shown by line symbols*
- *The identification of features from given co-ordinates*
- *The difference in latitude or longitude between features*

Answers

- *All answers to be one to five words or numbers.*
- *At least half the answers must be co-ordinates*

General guidelines

- *Write down questions and answers as they occur to you.*
- *No more than 2 questions to relate to theory*
- *Majority of questions must be based on the accompanying map extract.*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer used unaltered in the publication of MapTrix 2 will be remunerated. Please add your name and contact details at the end of the worksheet.

Bearing

♣

Even Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	ü
1	Direction	ü
2	Position	
2	Bearing	
3	Height	
3	Distance and area	
4	Gradients	
4	Profiles	

N.B. Only spatial analysis skills ticked off above can be assumed when formulating questions for map use exercises

Key Questions:

- Who uses bearings as part of their work?
- In which sport is bearing used?
- What does bearing mean?
- In what units is bearing measured?
- What is the difference between true and magnetic north?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skill (Learning Outcome 1) relative to bearing, when they can:

- Identify the places from and to which bearing is to be measured and accurately join the points
- Construct a north line on a map at the point from which bearing is to be measured
- Accurately measure the bearing between two points
- Explain the difference between true and magnetic bearing
- Calculate magnetic bearing.

Appropriate resources:

- A lesson on bearing (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. a compass, an illustration of a compass, pictures of ships or aeroplanes, etc)

Instructions

Questions

*Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to **bearing**.*

Question content could relate to:

- *Calculating bearing between given places*
- *Identifying features from given bearings*
- *Aircraft navigation*
- *Orienteering*
- *Calculating current bearing from given information about magnetic declination and change.*

Answers

- *All answers to be one to five words or numbers or a construction.*
- *Two answers to be bearings < 90°.*
- *One answer each should be between 90°-180°, 180°-270°, 270°- 360°.*
- *A maximum of 3 questions to include magnetic bearing*
- *Some answers should be places (found using bearings)*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer used unaltered in the publication of MapTrix 2 will be remunerated. Please add your name and contact details at the end of the worksheet.

Height

♦

Odd Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	ü
1	Direction	ü
2	Position	ü
2	Bearing	ü
3	Height	
3	Distance and area	
4	Gradients	
4	Profiles	

N.B. Only spatial analysis skills ticked off above can be assumed when formulating questions for map use exercises

Key Questions:

- How is height represented on topographic maps?
- What is the difference between height and altitude?
- Which professionals need to read altitude from maps?
- What is meant by mean sea level?
- In what units is height measured?
- How do contour patterns represent different slopes and relief features?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skill (Learning Outcome 1) relative to assessing height from a map, when they can:

- Identify at least four height clues on a map
- Explain how contour lines are used to show height
- Show how drainage patterns indicate relief
- Find the height of any place on a map
- Interpolate height
- Calculate the difference in height between places on the map.

Appropriate resources:

- A lesson on height and general relief (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. horizontal photograph, 3D model, stereo pair, stereoscope, etc)

Instructions

Questions

*Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to **height**.*

Question content could relate to:

- *Use of all 4 height clues (trig. beacons, bench marks, spot heights, contours) and drainage patterns*
- *Calculating altitude of features*
- *Identifing relief features from contour patterns*
- *Relationship between relief and infrastructure*

Answers

- *All answers to be one to five words or numbers.*
- *At least 2 answers must be heights read directly off contours*
- *At least two answers must be interpolated heights*
- *At least two answers must be differences in altitude*
- *Some answers must be places found from heights*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer used unaltered in the publication of MapTrix 2 will be remunerated. Please add your name and contact details at the end of the worksheet.

Distance and Area

♦

Even Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	ü
1	Direction	ü
2	Position	ü
2	Bearing	ü
3	Height	
3	Distance and area	
4	Gradients	
4	Profiles	

N.B. Only spatial analysis skills ticked off above can be assumed when formulating questions for map use exercises

Key Questions:

- How is distance represented on topographic maps?
- What is the difference between large and small scale maps?
- How can distance be calculated from maps?
- How can area be calculated from a map?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skill (Learning Outcome 1) relative to calculating distance and area from a map, when they can:

- Use more than one type of scale to calculate distance
- Measure and calculate straight line distance
- Measure and calculate curvilinear distance
- Express answers in different units of measurement
- Calculate the area of land parcels with quadrilateral and irregular shapes using at least three different methods.

Appropriate resources:

- A lesson on distance and area (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. maps of different scales, opisometers, calculators etc)

Instructions

Questions
*Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to **distance and area**.*

Question content could relate to:

- *Real distances travelled using various modes of transport*
- *Calculating differences between straight line and transport route distance*
- *Length of fences or other boundary lines*
- *Area of land parcels with regular and irregular shapes*

Answers

- *All answers to be one to five words, numbers or a construction.*
- *At least 2 answers must be in metres and 2 in kilometres*
- *At least one answer must be in m² and one in km²*
- *At least two answers must be differences in distance*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details
Authors of each question and answer used unaltered in the publication of MapTrix 2 will be remunerated. Please add your name and contact details at the end of the worksheet.

Gradient

♠

Even Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	ü
1	Direction	ü
2	Position	ü
2	Bearing	ü
3	Height	ü
3	Distance and area	ü
4	Gradients	
4	Profiles	

N.B. Only spatial analysis skills ticked off above can be assumed when formulating questions for map use exercises

Key Questions:

- What is gradient?
- Why is gradient important?
- In what ways can gradient be expressed?
- The work of which professionals or sport enthusiasts relies on calculation of gradient?
- How does gradient influence settlement patterns and infrastructure?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skill (Learning Outcome 1) relative to gradient, when they can:

- Explain what gradient is and how it can be described and measured
- Identify a slope from given points
- Calculate gradient
- Discuss the influence of gradient on patterns of settlement, infrastructure and land use.

Appropriate resources:

- A lesson on gradient (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. horizontal photograph, 3D model, etc)

Instructions

Questions

*Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to **gradient**.*

Question content could relate to:

- *Use of all height clues*
- *Recognition of contour patterns*
- *Calculating altitude*
- *Calculating gradient*
- *Suitability of gradient for different ascent/descent purposes*
- *Influence of gradient on infrastructure, settlement etc.*

Answers

- *All answers to be one to five words or numbers.*
- *At least 2 answers must be height differences read directly off height clues*
- *At least two answers must be interpolated height differences*
- *At least two answers must be distances*
- *Balance of answers should be calculated gradients.*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer, used unaltered in the publication of MapTrix 2, will be acknowledged and remunerated. Please add your name and contact details at the end of the worksheet.

Profiles

♠

Odd Numbers

Please write down the suit and number of this work card on the accompanying worksheet.

Assumed prior knowledge: Topographic map reading

Competence in topographic map reading with ability to distinguish between, recognise and comprehend map symbols and how they represent both natural and constructed geographic features.

Relationship of this skill to other map analysis tasks

Spatial analysis hierarchy

Difficulty level	Skill	Assumed prior skills
1	Boundaries	ü
1	Direction	ü
2	Position	ü
2	Bearing	ü
3	Height	ü
3	Distance and area	ü
4	Gradients	
4	Profiles	

N.B. Only spatial analysis skills ticked off above can be assumed when formulating questions for this map use exercise

Key Questions:

- What is a profile?
- How do profiles help us understand relief?
- How are profiles constructed?
- Which professionals or sport enthusiasts use profiles?
- What is the difference between a cross-section and a profile?

Please write down any additional key questions on the accompanying worksheet.

You will know that learners have attained the knowledge and geographic enquiry skill (Learning Outcome 1) relative to profiles, when they can:

- Explain what a profile is and how it can be constructed
- Construct a profile between selected points on a map
- Use a profile to identify slope forms
- Use a profile to determine intervisibility
- Calculate the vertical exaggeration of a profile
- Match a given profile to the correct area on a map

Appropriate resources:

- A lesson on profiles (still to be drafted)
- Topographic map extract

Please write down any other resource that you would like to recommend (e.g. horizontal photograph, stereo pairs, stereoscope, 3D model, etc)

Instructions

Questions

Please formulate 10 questions and answers that will demonstrate that learners have attained the required knowledge and skills relative to ***profiles****.*

Question content could relate to:

- *Interpretation of contours and drainage patterns*
- *Profiles along straight lines (e.g. a railway) as well as curvilinear lines (e.g. rivers)*
- *Calculating vertical exaggeration*
- *Suitability of area for different land use purposes*
- *Identifying the position of a given profile on a map*

Answers

- *Answers to be one to five words, a number or a construction.*
- *At least one answer must refer to intervisibility*
- *At least one answer each must be a height and a distance interpolated from the profile*
- *One answer should be a vertical exaggeration.*

General guidelines

- *Write questions and answers as they come to you.*
- *Try to frame questions in the context of the map area and learner interests.*
- *At least 8 questions must be based on the accompanying map extract (no more than 2 theory questions).*
- *Before the end of the session, number the questions from easiest to most difficult.*

Contact details

Authors of each question and answer used unaltered in the publication of MapTrix 2 will be acknowledged and remunerated. Please add your name and contact details at the end of the worksheet.

Appendix 7.1

Scorecard for MapTrix Digital Game

Print or copy this scorecard and file for your CASS portfolio

Name:-   **Date:-**

Start with any suit
Select 12 cards and fill in the number or letter for each one
Play the cards you have selected by answering the 10 questions on each one
Record your results by entering 1 for each correct answer beside the question number
Add score downward then shade the bar representing your total on the corresponding graph below
Add score sideways and refer to self-check screen for help if necessary

TRIAL RUN
♣♦♥♠ ?
No. ?
✓ = 1
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Total

Hearts	Picture	Odd	Even	Self-check
Fill in ⇨				
Question	Score	Score	Score	
Q1				
Q2				
Q3				
Q4				
Q5				
Q6				
Q7				
Q8				
Q9				
Q10				
Total				

Spades	Picture	Odd	Even	Self-check
Fill in ⇨				
Question	Score	Score	Score	
Q1				
Q2				
Q3				
Q4				
Q5				
Q6				
Q7				
Q8				
Q9				
Q10				
Total				

Clubs	Picture	Odd	Even	Self-check
Fill in ⇨				
Question	Score	Score	Score	
Q1				
Q2				
Q3				
Q4				
Q5				
Q6				
Q7				
Q8				
Q9				
Q10				
Total				

Diamond	Picture	Odd	Even	Self-check
Fill in ⇨				
Question	Score	Score	Score	
Q1				
Q2				
Q3				
Q4				
Q5				
Q6				
Q7				
Q8				
Q9				
Q10				
Total				

Graph your progress on the charts below by shading each bar to represent your score

	Hearts Rural Settlement			**Spades Landscape**			**Clubs Urban Settlement**			**Diamonds Transport**		
Score												
10												
9												
8												
7												
6												
5												
4												
3												
2 ⇧												
1												
Shade	Picture	Odd	Even	Pictur	Odd	Even	Picture	Odd	Even	Picture	Odd	Even
⇨ Fill in card												
	Subsistence Farming	Primary economic activities	Commercial agriculture	Plains	Mountains	Valleys	Large cities	Industrial areas	Small towns	Various types	Railways	Road netweoks

Mastering the skill of map reading is the foundation for topographic map analysis and interpretation.
This is a requirement of FET Learning Outcome 1 Geographical Skills and Techniques

Appendix 7.2

ADVERTISING LEAFLET

FREE TOPOGRAPHIC MAP ANALYSIS COURSE

WHERE?
University of Cape Town, Main Campus
SCILAB C on the 2nd Floor of R.W. James Building

WHEN?
Course duration (depends on proficiency level): 10 to 16 hours, over 5 to 8 sessions between Monday 2 July and Thursday 12 July (during mid-year vacation)

HOW?
Computer assisted training course based on *MapTrix*.
All potential participants will complete a pre-test to gain access to the course.
Participants are required to commit to completion of the course and a post-test.

WHO?
Course is offered to Geography teachers, students and learners who need to analyse topographic maps. Only a limited number of places are available. Booking is essential.

INTERESTED?
Bookings now open. Contact Lorraine Innes to get more information.
Call or fax 021 761 6886.
Call or sms MAP SKILLS COURSE to 083 702 4003
or email lorraine@maptrix.co.za

Appendix 7.3

DETAILS OF THE SCHOOL-BASED TRIALS OF THE MAPTRIX DIGITAL GAME

GROUP SX

1. Participation in the trials

Because the participant numbers were so low in the first trial, it was necessary to run further trials. In a social discussion with a geography staff member from one of the schools near UCT (school SX on the map in Figure 7.4), that had received the letter of request and pamphlet, it was mentioned that the holiday trial had been too small to be definitive. The researcher was invited to run further trials of the learning materials at her school with two Grade 10 classes. A presentation was made to the Headmaster, Deputy Head, the IT staff member responsible for network management, the matric geography teacher plus the teacher responsible for one of the two Grade 10 class groups that were to be involved in the trial. The Headmaster granted permission for the trial on condition that the provincial education department gave approval. The staff agreed to offer support and assistance. Approval was received from the Western Cape Education Department on condition that the names of the school, staff and learners would not be revealed and that the department would be appraised of the results. The time period allocated to the trials at the school was from Monday 3 September 2007 to the end of the school term on Friday 21 September 2007.

2. Historical background of the school

This English medium school was founded when a suburban boys' high school and a girls' high school were amalgamated. It provides high school education to children living in a middle income residential area relatively close to the CBD of Cape Town. In its early years the school population was strictly white in accordance with the apartheid policies of the time. After 1994 when it became policy to open schools to all races, it quickly transformed to an integrated school of which an increasing percentage of the learners came from areas formerly reserved for people designated by the apartheid regime as Coloured. Many did not have English as their only home language. In recent years a large number of Xhosa-speaking learners have joined the school population. This is largely due to the school's location close to one of the major metropolitan highways linking outlying, low-income residential areas to the city (see Figure 7.4 for the location of Guguletu and Khayelitsha on the N2). While this transport corridor makes it relatively easy for learners to gain access to the school from their homes, the daily commute often takes its toll on time and limited financial resources.

3. Computer facilities

The IT Department is easily accessed in the main building of the school. The computer facilities comprise two interconnected computer laboratories equipped with enough terminals for each learner to work independently. A large screen television is linked to a teacher's terminal in the larger room. The terminals receive constant attention and none malfunctioned during the trial. Arrangements were made to accommodate the Grade 10 learners in the laboratories during their scheduled geography lesson periods. It was most fortunate that there were open slots in the IT Department's timetable. Once the trials were underway the larger of the two classes was split so that only one of the computer laboratories was required at a time because there was a clash with another class. The teacher of the larger group taught half the class in the geography classroom while the researcher worked with the other half. This arrangement was alternated thus resolving the pressure on the computer facilities but reducing contact time with the learners.

4. Staff available to assist with trials

The smaller class was being taught by a geography-trained specialist with a keen interest in map use. The larger class was in the temporary care of a biology-trained teacher who had taken over the class while a regular geography department staff member was indisposed. Both staff members remained with their classes during the trials and offered valuable assistance with general classroom management. The teacher of the smaller class engaged with the map reading programme alongside the learners. She actively participated during the introduction to the map analysis programme and afterwards expressed an interest in receiving training in the programme to better assist learners if and when this phase of the trial went ahead.

The assistance of the teacher of the larger class was much appreciated. The learners tended to be restive and unruly especially during the introductory lessons. When the group was split, he was no longer able to remain in the computer laboratory as he was teaching the other half of the class. Throughout the trial and especially once the larger group was split up, the two members of the IT Department made themselves available to offer assistance, both with technical matters and with discipline. The co-operation and support of all staff members with whom the researcher interacted during the trial, was greatly appreciated.

5. Timetable

Table A7.3.1 Trial timetable for Group SX - MapTrix Digital Game

Date in Sept. 2007	Small class	Time - minutes	Large class	Time - minutes
3	Participant information form Opening questionnaire Map reading pre-test		Participant information form Opening questionnaire Map reading pre-test	
4			Map analysis pre-test Partial computer session	30
5	Map analysis pre-test Card selection		Computer session 1	60
10	Computer session 1	60	Computer session 2	60
11	Computer session 2	60	Computer session 3 (½ class)	30
12	Computer session 3	60	Computer session 4 (½ class)	30
13	Computer session 4 (Pilot group moved on)	60		
14	Computer session 5 Introduced MapTrix Geomatica			
17	Map reading post-test			
19			Computer session 5 (½ class) Map reading post-test (½ class)	30
20			Rest sat map reading post-test	
Total time available		**240 (4 hrs)**		**240 (4 hrs)**

The time available for the trials with Group SX was from Monday 3 September 2007 to the end of the school term on Friday 21 September (Table 1). The school runs a fortnightly timetable cycle, the trial started mid-way through a cycle. During a regular two-week timetable cycle there are 8 geography periods of 60 minutes each. During the three weeks of the trial this gave a potential total of 11 lesson periods with the small class and 13 with the large class (due to the uneven spread of lesson periods per week). Two days were lost because the researcher had a prior engagement and the teacher of the smaller class requested an additional lesson period. Lesson periods were also lost when the school timetable was changed unexpectedly to accommodate end of term testing. Unfortunately the many deviations from the time table reduced the actual contact time with classes to 8 and 7 periods respectively. Of these periods, 3 were classroom based for introducing the programmes and for the pre-and post testing. This meant that the small class spent only 5 periods in the computer laboratory and the large class only 4 periods (Table A7.3.1). After a disastrous attempt to introduce MapTrix Geomatica to the smaller class, the trial was abandoned.

Both classes had four hours available to play the MapTrix Digital Game after which arrangements were made to have the classes sit the map reading post-test. The individual times were calculated based on the number of cards played in the available time. Unfortunately the closing questionnaire was not completed by members of this group.

6. Implementation

Although a period of three weeks was made available, due to various problems, only four computer periods could be used effectively. The trial venues were both the classrooms of the two classes as well as the two computer laboratories at the school. Prior to the first computer period, the prototype MapTrix Digital programme was loaded onto the server and downloaded onto each terminal. A shortcut icon was placed on each screen so that learners could access the programme without any delay.

During the first classroom lesson with each group, the background to the research programme was explained and learners were asked to complete a participant information sheet (Appendix 8.1). They were asked to have these signed by parents/ guardians giving permission for their participation in the educational research project and to return these the next day. Next they completed an opening questionnaire (Appendix 8.2). Although time was limited, it was hoped that they would then complete the map reading and map analysis pre-tests.

During the first lesson with the smaller class it became clear that the plan was too ambitious. Forms were filled in and the map reading pre-test completed (Appendix 8.3). The map analysis pre-test was started and then the bell rang (earlier than expected) for change of class. During the second lesson with this class the map analysis test was completed (Appendix 8.4) and then the MapTrix Digital Game was explained. Learners were asked to pre-select twelve playing cards representing the geographic themes covered in the MapTrix programme (Appendix 8.7).

The process of marking their answers, recording their scores and graphing their progress on the scorecard (Appendix 7.1) was explained so that they would be ready to start playing the game in the computer laboratory at the next lesson During the third period they started the intervention and were soon actively engaged in the learning game.

In the first classroom period, the larger class took a considerable amount of time to settle down; class members were talkative and unruly. They eventually completed the participant information sheets and the questionnaire and just managed to complete the map reading test before the bell rang. During the second classroom period the map analysis test was attempted. Most learners were unable to answer the questions and again became restive. The group was then moved to the computer laboratory where there was just enough time to introduce the MapTrix Digital Game. At the start of the third lesson the rules of the game were explained, they made their playing card selection and started the intervention.

From the fourth period onward learners in both classes settled down to work on the programme, most were consistent in their efforts to complete the exercises. Constant reminding was necessary to get the learners to fill in their scorecards correctly. Learners were set the task of completing the game by playing 12 cards, one on each of the concept lessons. Apart from a few learners who took special care to be neat, work was generally untidy and careless.

Between teaching periods in the computer laboratory, the MapTrix Geomatica Prototype was loaded on the server and then installed on each terminal. The network manager took great pains to demonstrate the process, explaining to the researcher how to copy and paste the installation programme and then the TNT Mips atlas data. The programme was opened on each terminal and the path between the software and the data established so that when learners came in for the lesson they could go straight into the GIS programme. Shortcut icons were placed on each screen.

The fewer learners in the small class made it possible to monitor the progress of individuals. Those who had high scores on the pre-test were watched closely and by the sixth lesson a small group were moved from the larger computer room to the smaller venue and introduced to the MapTrix Geomatica prototype. It was explained that by introducing the programme to them before the others, they were to assist as peer tutors when the rest of the learners were introduced to the more advanced programme. They enjoyed the challenge and were soon able to zoom in to the local area and find the location of the school.

During the seventh lesson the rest of the small class was introduced to the MapTrix Geomatica prototype. Several problems were encountered which made the lesson chaotic. Although the programme had been installed on the teacher's terminal, which was linked to the large TV monitor, it had not been placed on the same drive (nor had the path been established between software and data). Before the programme could be opened, the learners all had to log out of the student profile and log onto the GIS profile, which had been specially created for the trials. Because most learners were familiar with the normal set-up, they resisted changing the login process. Although the link had been established between TNT Mips and the atlas data, the file path had not been saved so this process had to be repeated for each terminal. Without the TV monitor for demonstration purposes, this process had to be explained repeatedly.

By the time the programme was up and running on each terminal it was almost time to end the lesson. Rather than helping their peers, the learners who had previously been introduced to MapTrix Geomatica moved ahead, following the instructions but repeatedly calling for assistance when they could not go any further on their own. The lesson ended on a sour note for a very frustrated researcher and a rather disgruntled geography teacher.

Lesson time with the large class was reduced by various factors over which the researcher had no control. An enormous traffic jam caused by striking municipal workers resulted in such highway chaos on Monday 10 September that many learners coming in from the outlying residential areas abandoned their journeys to school. On Tuesday 11 September almost half the class were missing due to their participation in a drama practice. A band practice in the school hall on 12 September distracted learners who were eventually rounded up and returned to the computer laboratory late for the start of their session. Due to an unforeseen IT timetable clash it was necessary to split the large class so that only the one laboratory was used. The teacher supervised the other half of the class in the classroom and the two halves alternated time in the computer laboratory. As a result of the reduced computer time, this class lagged behind the smaller one in completing the MapTrix Digital Game and there was no opportunity to introduce them to the MapTrix Geomatica programme.

It was clear that both programmes could not be completed in the available three weeks. It was decided to abandon any further attempt to introduce MapTrix Geomatica and rather to conduct a full evaluation of the MapTrix Digital Game by making sure the learners completed the map reading post-tests before the end of the term. While the two classes of Grade 10's thus provided valuable data on the MapTrix Digital Game, the objective of trialling MapTrix Geomatica was not met at this school. The end of the school year was rapidly approaching and a third trial venue had to be found.

Appendix 7.4

DETAILS OF THE SCHOOL-BASED TRIALS OF MAPTRIX GEOMATICA

GROUP PB

1. Participation in the trials

When pamphlets advertising the Free Topographic Map Skills Course (Appendix 7.2) were distributed to local schools, one of the private schools had already closed for the mid-year holidays (see school PB on the map in Figure 7.4). In the last term of 2007 the researcher approached the Head of Geography at the school and explained her dilemma regarding the low numbers of participants for the MapTrix Geomatica Trials. The number of participants in the first trials had been negatively impacted by the teacher's strike. The first school-based trial had not included the map analysis programme. When she requested permission to trial the MapTrix Geomatica prototype, he agreed to allow a class of Grade 10 boys to participate. Because the reputation of the teacher as an outstanding geography educator and map use specialist was well known, it was assumed that the boys would not require map reading skills improvement.

2 Historical background of the school

This private church school for boys was founded in the mid 1800's. The character of the student body has remained largely unchanged during a phase of rapid change in state schools. This is because the school, along with other private church schools, opened its doors to pupils of colour long before the end of apartheid politics in 1994. High fees and high academic entrance qualifications have ensured a generally privileged, almost homogeneous student body with the majority of boys coming from English home language backgrounds.

3 Computer facilities

All boys in Grades 8, 9 and 10 at the school are equipped with laptop computers which are used to foster self-study and the development of high-level computer skills. The boys had been introduced to two GIS packages – ArcView and Geomatica and enjoy some degree of familiarity with them both.

4 Staff available to assist during trial

The Head of Geography introduced the research project and distributed the opening questionnaires and the participant information forms in the week before the trial started. His broad experience of using GIS in the classroom and knowledge of the Geomatica Product Suite was extremely valuable. He loaded the prototype MapTrix Geomatica programme following the setup procedures he had used with other GIS software on all the boys' laptops prior to commencement of the trial. It was later discovered that his installation procedure was not efficient on all makes of laptops and the programme had to be reinstalled on some machines. During the trial he remained with the class at all times.

5. Timetable

TableA7.4.1 Trial timetable for Group PB - MapTrix Geomatica

Number of sessions	Duration of work sessions	Minutes	Hours
7 class periods	45 minutes	315	5.25
2 homework periods	30 minutes	60	1.00
Total time available		375	6.25 (6 hours 15 minutes)
Average time for each lesson (and exercise)		53.57 (54)	

With Group PB the trial was conducted during nine normal timetabled geography periods (Table A7.4.1). The teacher responsible for the class introduced the research and handed out the participant information sheets (Appendix 8.1) and opening questionnaires (Appendix 8.2) for completion ahead of the first period. Two further periods were used for the map analysis pre-tests and post-tests (Appendix 8.4) and closing questionnaire (Appendix 8.6).

Time available for the MapTrix Geomatica trial was seven forty-five minute periods to work on the map analysis programme in class plus learners were asked on two occasions to complete an exercise within half an hour for homework. This was possible because they each had their own laptops. Only seven lessons were covered because there was not enough time to complete the eighth lesson on profiles. It was not necessary to offer the MapTrix Digital map reading programme because the map reading pre-tests showed a high level of proficiency.

Time taken by Group PB was difficult to estimate because some learners were absent from class and a daily attendance register was not available. Although they were asked to dedicate two work sessions to the programme outside of class time, few did so. In order to calculate an approximate time spent on the programme the average time spent on lessons by those who did complete the programme was calculated (54 minutes) and multiplied by the number of exercises that each of the other participants completed. The time data entered represents the product of the number of exercises completed and the average estimated time. Unlike the other three groups in the MapTrix Geomatica trial, participants in this group did not always mark their own answers.

6. Implementation

Setting aside the pre- and post-test periods there were 7 teaching periods available for the 8 map analysis lessons between 15 and 26 October 2007. It was accepted at the start that there would probably not be time to complete all the lessons. In an attempt to get through as much of the programme as possible it was necessary for the boys to complete some of the exercises for homework. This meant that the learning environment would not be under the control of the researcher and teacher at all times. For this reason, it was decided to de-activate the link to the answers to the questions in the programme. This would remove the temptation to copy answers without working them out. Recognising that immediate feedback is important in the self-instruction methodology, all answer sheets were printed out and copied with the intention of handing them to the boys to assess their answers as they finished each exercise.

Once the pre-tests had been written, the second period was spent reviewing the program structure and introducing the lesson on Boundaries following the guidelines recommended by the computer programme developers (Appendix 8.8). The next period was spent completing an exercise on Boundaries. Before the end of the lesson they were handed the answer sheets to mark their answers. They were asked to follow the lesson on Direction and to complete the exercise for homework.

When reviewing the boys' standard of marking their first exercises, evidence of cheating was found. They had been instructed to write answers in ink and to mark answers in pencil or another colour ink. This instruction had been ignored. The same medium had been used to answer and mark answers. Many 'wrong' answers were crossed out and correct answers substituted. In other cases, the same wrong answers appeared on more than one script indicating copying. Mark allocations had been inflated to produce better scores.

At the start of period four the homework exercise sheets were collected and the next lesson, on Position, was briefly reviewed. Boys were instructed to go through the lesson carefully and to finish one of the two optional exercises in class. One or two boys finished early and asked for an answer sheet to assess their answers. The rest of the exercises were collected at the end of the lesson for marking by the researcher. In this case, answers from the answer sheet (which had been proved incorrect during the first trial) appeared on many scripts. This indicated once again that boys had cheated.

During the next period the issue of cheating was addressed. The principle of self-instruction was once again outlined, stressing the importance of honesty and self-respect combined with the need to make answers available only once they had been attempted by the learner. The most important aspects of the Bearing lesson were then demonstrated and the boys were instructed to go through the whole lesson and then complete one of the alternate exercises in class. A very small minority of the boys went ahead with the programme. Most waited for group instructions and would not follow the principles of self-instruction.

It was alarming to discover half-way through the trials that despite efforts to sort out problems with the prototype MapTrix Geomatica programme on some laptops, there were still some boys who could not access the programme files. Unfortunately they had been reticent in disclosing their difficulties, preferring to engage with other materials on their laptops while pretending to be working through the learning programme. A call to the technician who had assisted with the first trial helped resolve the technical problems.

Some of the boys were experiencing unrelated technical problems and were instructed to get their laptops to the school helpdesk without delay but were tardy in following this advice. Other boys neglected to bring their laptops to class for each lesson. Despite these technical pitfalls and the fact that some boys had not been handing in all the class or homework exercises, the trial programme went ahead.

The lesson on Height was reviewed in class and the boys set to work on the accompanying exercises which were handed in for marking. They moved on to the lesson on Distance and Area during the second of the two periods of the day and the exercises were set for homework. On the last available day Gradient was reviewed and the exercises set for class work. The previous day's homework was collected (by the few who had completed it) and boys were instructed to complete the exercises on Gradient in class or for homework. The following day the last few exercise sheets were collected, the post-tests were written and the closing questionnaire distributed for completion.

Appendix 7.5

DETAILS OF THE SCHOOL-BASED TRIALS OF MAPTRIX GEOMATICA

GROUP PI

1. Participation in trials

From a school in Hout Bay, far outside the 2,5 km radius of the campus, an invitation was extended to the researcher to trial the programme as part of a week-long year-end activity schedule (see school PI in Figure 7.4) Only two days were available for the intervention which was fitted in between trips to various local facilities to broaden the learners' environmental awareness (including a sewerage farm, a lighthouse and the aquarium). Not all participants took geography as a school subject but they were all IT students who were offered this opportunity to use an interactive, educational GIS package for the first time. Eleven Grade 10 learners sat the map analysis pre-test (Appendix 8.4). By the time the workshop started, two had withdrawn, leaving nine participants. The day before the intervention was due to start an additional volunteer from Grade 11 agreed to join the group and sat the pre-tests bringing the total to 10 participants. All participant information sheets (Appendix 8.1) were handed in. The envisaged target of 60 participants was reached before the end of the year.

Because the available time was limited and the academic standard of the learners was assessed by the organising teacher as high, the MapTrix Digital Game was not offered. Although there are two map analysis exercises available for each of the eight lessons in the MapTrix Geomatica programme, learners were instructed to complete only one exercise per lesson topic. Even with this attempt to reduce the time required by the learners to complete the programme it was anticipated that they would not all manage to do so.

2. Historical background of the school

Providing a contrast to the previous schools, this is a relatively new private school offering the Cambridge Curriculum. This school is furthest from the University being situated in Hout Bay, which has grown from a small fishing village into an attractive dormitory suburb of Cape Town. The group of boys and girls in Grade 10 who participated in the trial were being prepared for the examinations for the International General Certificate in Secondary Education (IGCSE).

3. Computer facilities

The school has a well equipped computer laboratory plus the Grade 10 learners are each allocated a laptop computer for their exclusive use during the school day. These are lodged at school and booked out and returned as required for specific lessons. This prevents the loading of unauthorised material, making it easier to focus learners' attention during lessons when they use the laptops in class. Other benefits of this storage system are that it facilitates maintenance of the machines and makes it possible to load programmes onto each laptop from the server outside of lesson time.

On Friday 16 November the researcher assisted school staff in the installation of MapTrix Geomatica. On the following Tuesday, the day before the start of the two-day intervention, a digital projector in the computer laboratory was used to introduce the learners to the programme (Appendix 8.8). This also provided the opportunity to ensure that the programme was working on all the laptops. The workshop started the following day and was held in the Science laboratory where there was ample space on the work surfaces to lay out all the learning materials.

4. Staff available to assist during trial

Unlike the other school trials where contact was established with geography staff members, at this school it was the Science and the Information Technology teachers who assisted with the trial. The Information Technology teacher supervised the installation of the programme on all the laptops and was available for assistance during the introduction of the MapTrix Geomatica programme using the digital projector in her laboratory. The science teacher, who wished to give the learners the experience of being part of an authentic research process, remained in the venues throughout the trial to assist with handling queries and to provide equipment, photocopies and support as required.

5. Timetable

With Group PI, pre-tests and opening questionnaires (Appendix 8.2) were conducted prior to the two-day intervention and the post-tests (Appendix 8.4) were conducted on the day following the trial. The time available was 9 hours and 15 minutes for the MapTrix Geomatica map analysis programme (Table A7.5.1). Time taken to work through the programme by each learner was entered on a personal timesheet for each day. Although some participants completed the programme in less than the available time, not everyone did. Total time was recorded to the nearest quarter hour.

Table A7.5.1 Trial timetable for Group PI - MapTrix Geomatica

Date	Session start	Session finish	Duration of session
28 November Wednesday	08:15	10:00	1 hr 45
	Break		
	10:30	12:00	1 hr 30
	Break		
	12:15	13:15	1 hr 00
	Break		
	13:30	14:30	1 hr 00
29 November Thursday	08:30	10:30	2 hr 00
	Break		
	11:00	12:00	1 hr 00
	Break		
	13:30	14:30	1 hr 00
Total time			9 hr 15 minutes

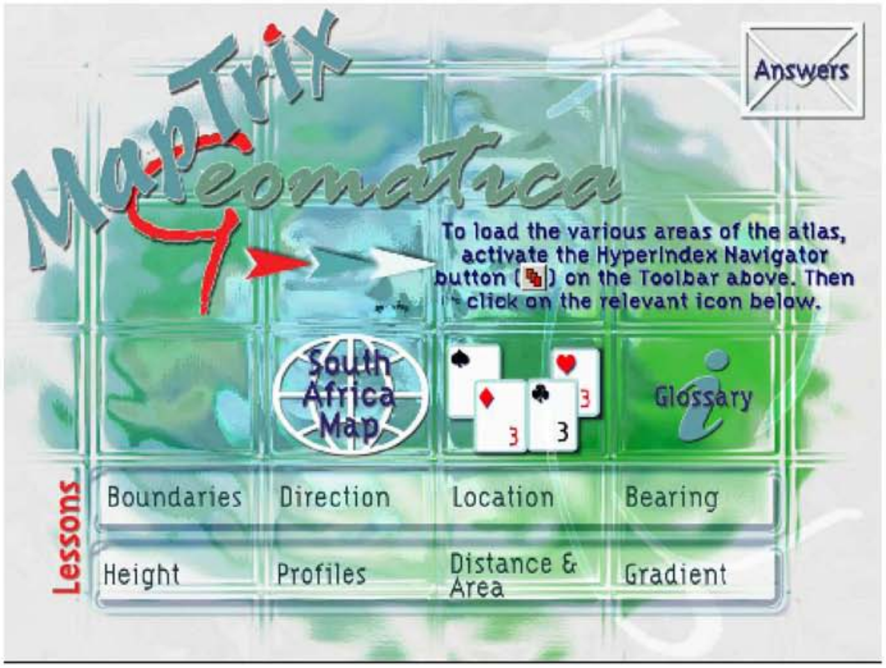
6. Implementation

A positive and co-operative atmosphere prevailed throughout the trials. Learners worked diligently through the lessons, the majority completing all of them. They worked through the answers to the exercises, some in consultation with their peers and others worked alone. Queries were answered by the researcher as they came up. On completion of each exercise, learners consulted the answers on screen and marked their own exercises.

Appendix 7.6

MapTrix Geomatica Lesson Introduction

1. After your own introduction, get the learners to load and open the MTG atlas
2. Explain the Main Menu options



   1. The South Africa Map
   2. The Cards
   3. The Glossary
   4. The Lesson area

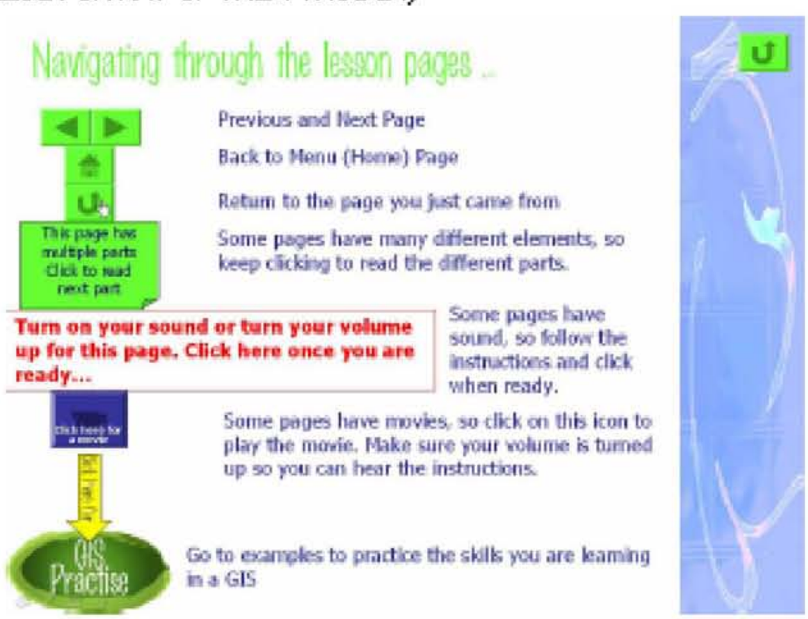
3. The show them how to activate the HyperIndex Navigator and explain how the cursor changes to a hand when a Hyperlink is available.

4. Click on and open the Boundaries Lesson (Lesson 1). This will open the Powerpoint Lesson

5. Talk about the first screen.

1. The Lesson Button
2. The GIS Lesson Button
3. How To Use the Lessons Button

6. Click on the How to Use the Lessons Button and go through what each of the navigation options do (DO NOT CLICK ON ANY OF THEM THOUGH)



Appendix 7.6 cont.

7. Use the  to return to the front page

8. Click on the GIS lesson button to go to the MTG Navigation Lesson

9. Introduce the idea of ALT TAB to switch between the Powerpoint lesson and the Atlas. **PRACTISE IT**

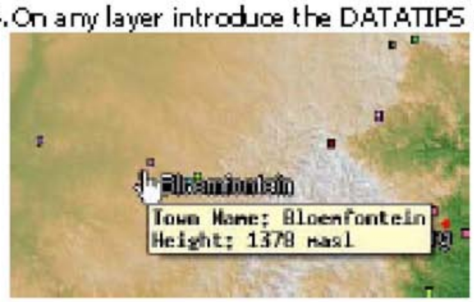
10. Talk about HyperIndex Navigating. Switch to the Atlas and hyperlink to the South African Map. Allow the learners to play with the Hyperlink tools on this map using the MTG areas.

Even run a little competition to see who knows what to do and how quickly they can do it!!

11. Then make sure you are back at the SA Map and introduce the LEGEND View.
12. Introduce the term 'LAYERS' and show how these are turned on an off

13. Then select a layer and play with the Zoom tools **especially:**
    - Full Screen 
    - Zoom In / Out 
    - Zoom Box 

14. On any layer introduce the DATATIPS and explain what they are showing

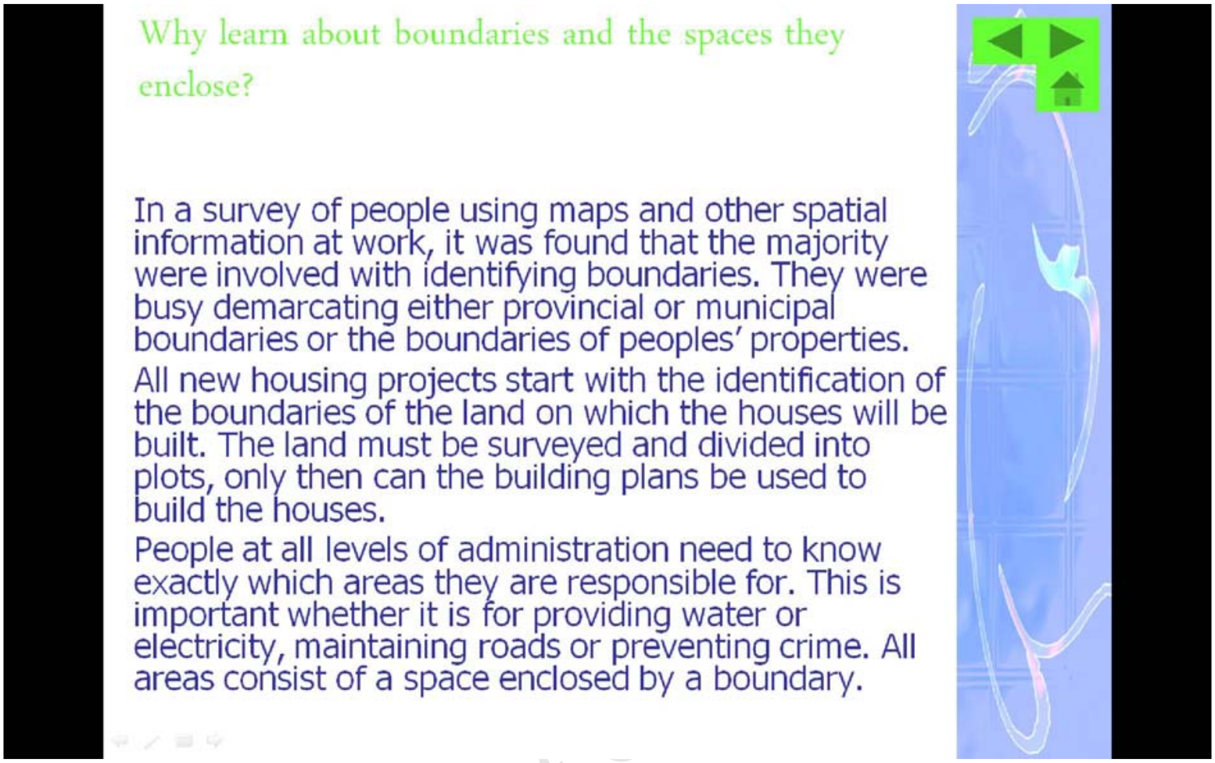


15. Return to the Powerpoint Lesson and close it (by pressing ESC)

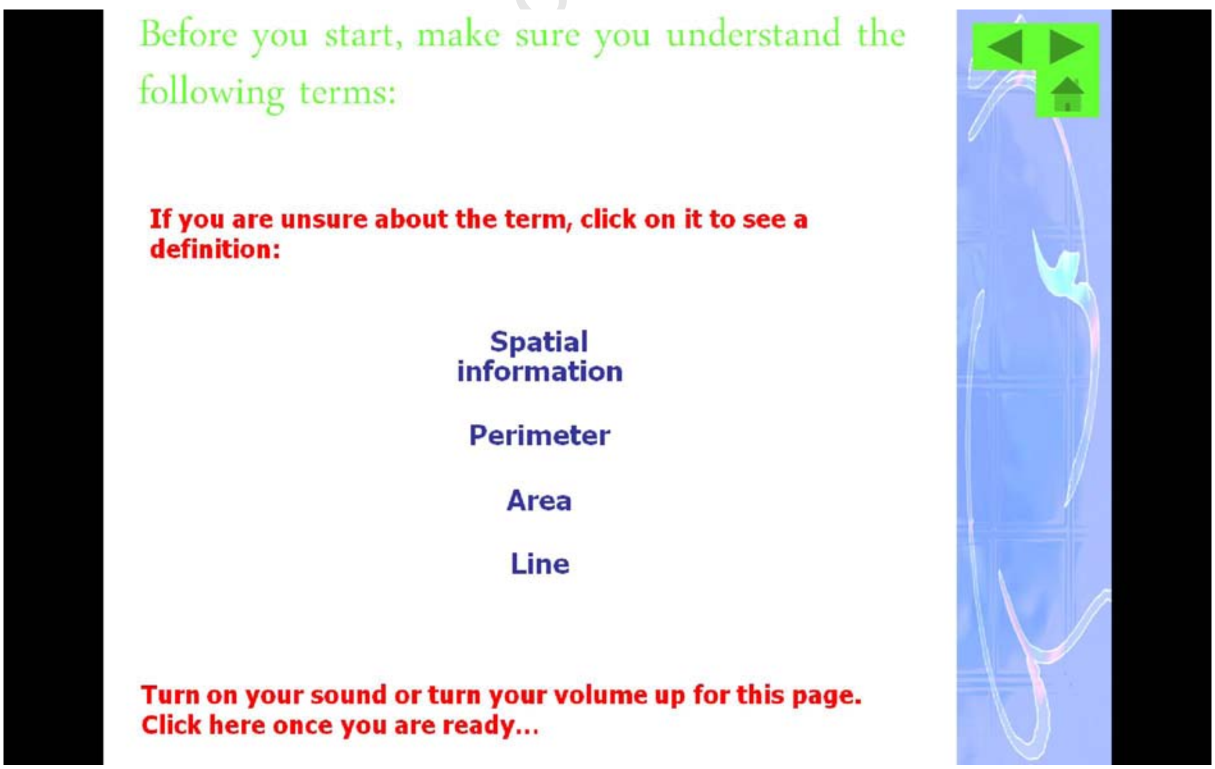
16. They should be ready to go now!!

Appendix 7.7

Selection of PowerPoint slides from MapTrix Geomatica lesson on Boundaries



A



B

What you need to know NEXT about boundaries and the spaces they enclose?

Boundaries on small scale maps

Examples of easily recognised boundary lines on small scale maps are:

- International boundaries
- Provincial boundaries

C

Your local boundary

The area within each province is divided into different kinds of administrative structures. The South African Constitution provides for 3 levels of municipalities.

- Metropolitan municipalities (6 in 2006) serving Johannesburg, Durban, Cape Town, Pretoria, East Rand and Port Elizabeth
- Local municipalities (231 in 2006) serving single, medium to large settlements
- District municipalities (47 in 2006) each serving a number of smaller settlements

D

Boundaries on topographic maps

Boundaries on medium scale maps are not always as easy to recognise as those on small scale maps.

Let's move on to the 1:50 000 topographic map of South Africa to learn more about boundaries and the spaces they enclose. There are many types of information on a topographic map. Sometimes it is hard to distinguish one area from another, especially if there is no difference in the colours used to show the areas. You need to identify the lines that mark the boundaries of different areas.

The following lines on topographic maps are shown as the edges (boundaries) around different land uses that are identified by their own area symbols.

- Recreation areas
- Firebreaks
- Excavations
- Built-up areas
- Cultivated land
- Orchards and vineyards
- Woodland

E

Boundaries on topographic maps

The following line symbols are used to show boundaries on topographic maps. The areas they enclose are not always specifically identified with their own area symbols.

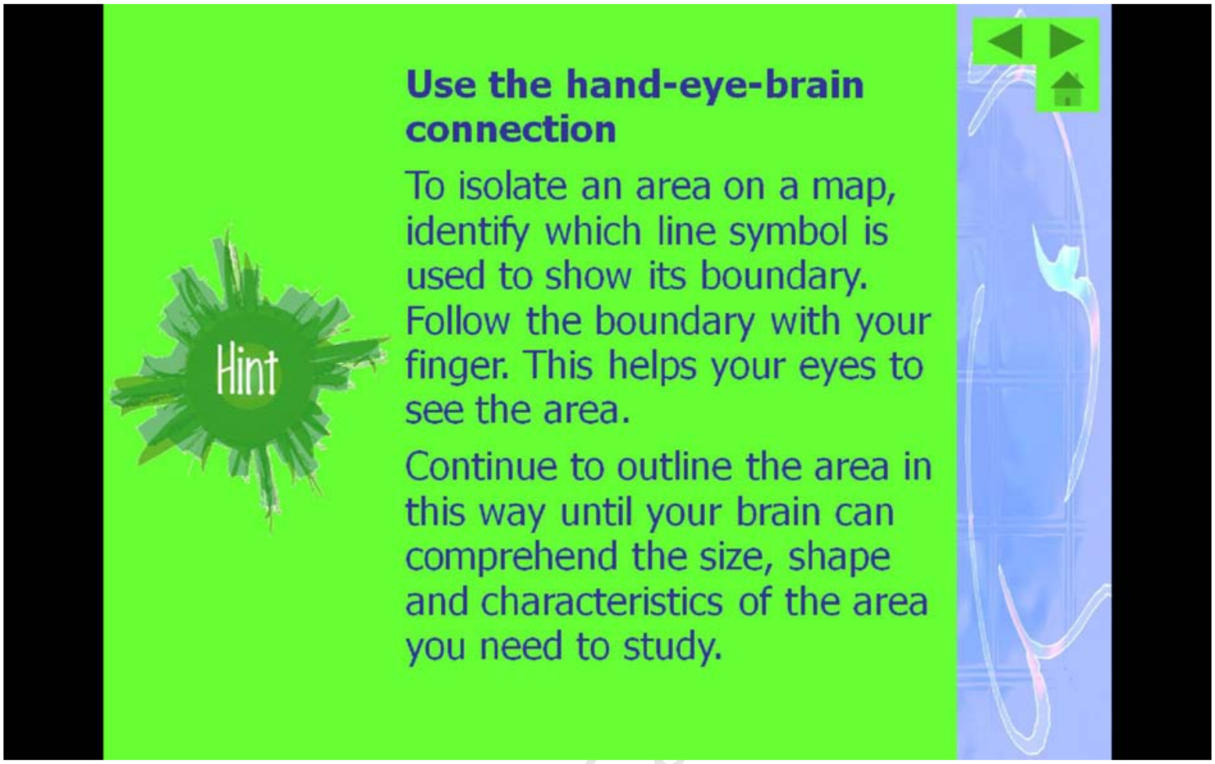
- Game reserve, nature reserve and state forest boundaries
- Fences
- Walls
- Original farm boundaries

Some lines form boundaries between different land and water surfaces

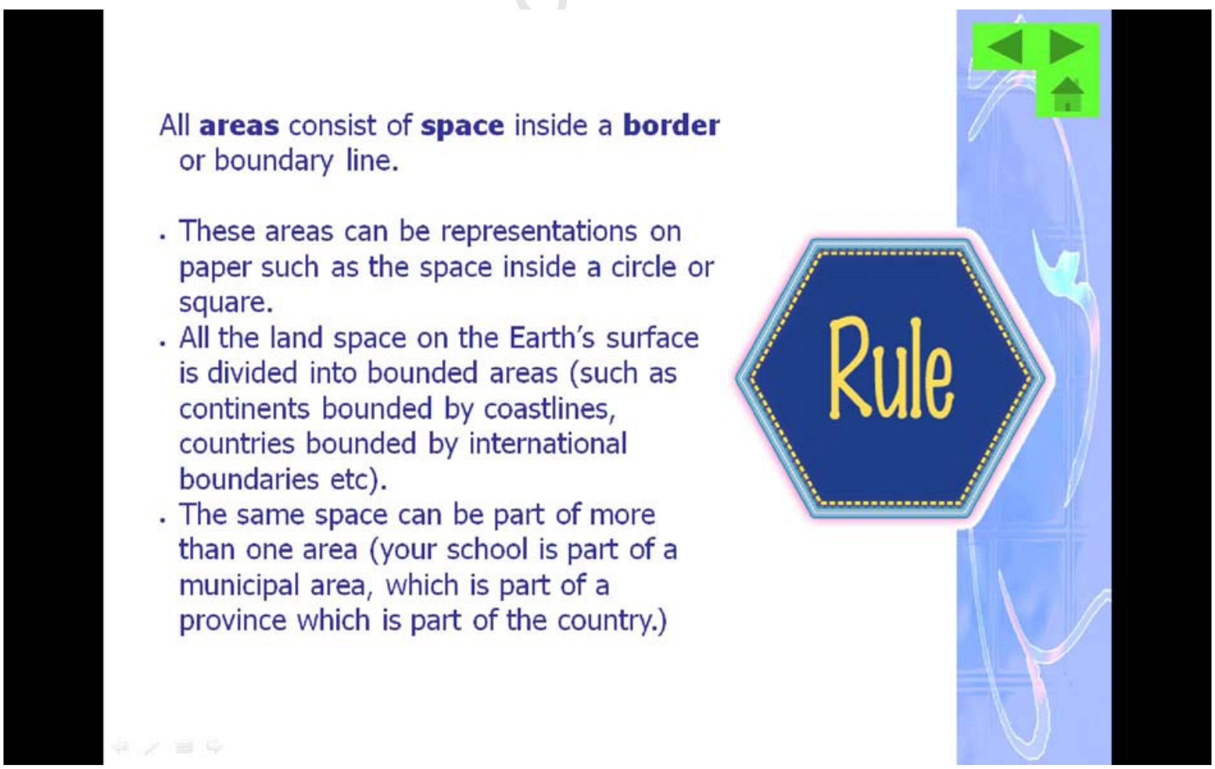
- Terraces at the edge of an eroded area
- The edge of a dry pan or dry water course
- The edge of a non-perennial pan or non-perennial water course
- A river bank
- The edge of a dam (which is always shown on the map at the highest possible water level)
- The coastline
- Contour lines

Yes, even contour lines are a kind of boundary - between land that is higher and land that is lower than a particular altitude.

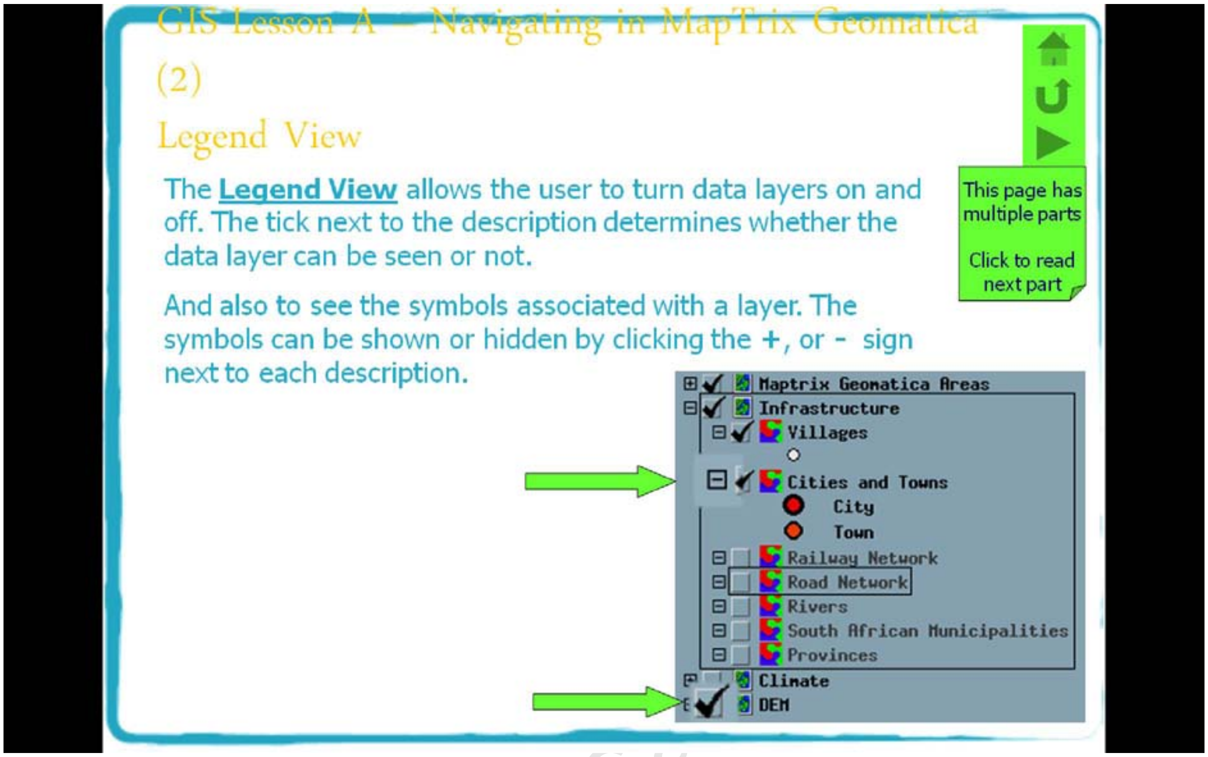
F


Use the hand-eye-brain connection
To isolate an area on a map, identify which line symbol is used to show its boundary. Follow the boundary with your finger. This helps your eyes to see the area.
Continue to outline the area in this way until your brain can comprehend the size, shape and characteristics of the area you need to study.
Hint

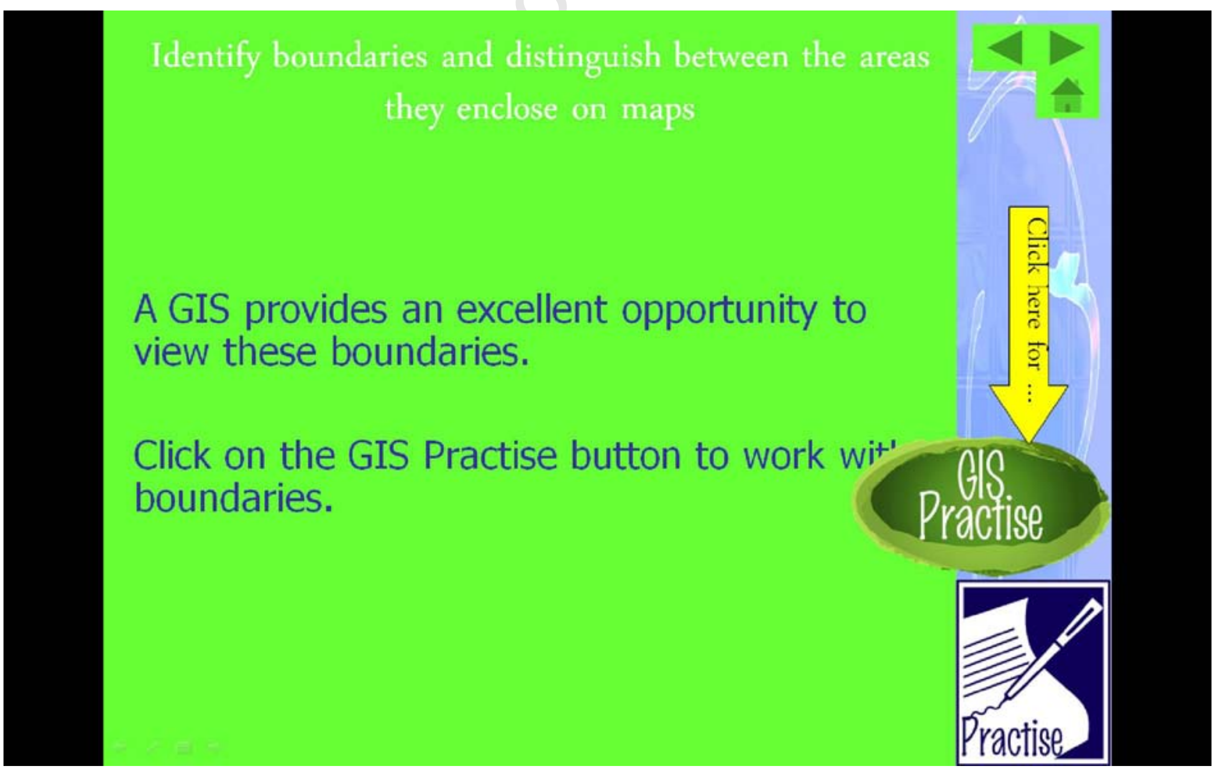
G


All **areas** consist of **space** inside a **border** or boundary line.
. These areas can be representations on paper such as the space inside a circle or square.
. All the land space on the Earth's surface is divided into bounded areas (such as continents bounded by coastlines, countries bounded by international boundaries etc).
. The same space can be part of more than one area (your school is part of a municipal area, which is part of a province which is part of the country.)
Rule

H


GIS Lesson A – Navigating in MapTrix Geomatica (2)
Legend View
The Legend View allows the user to turn data layers on and off. The tick next to the description determines whether the data layer can be seen or not.
And also to see the symbols associated with a layer. The symbols can be shown or hidden by clicking the +, or - sign next to each description.
This page has multiple parts
Click to read next part
Maptrix Geomatica Areas
Infrastructure
Villages
Cities and Towns
City
Town
Railway Network
Road Network
Rivers
South African Municipalities
Provinces
Climate
DEM

I

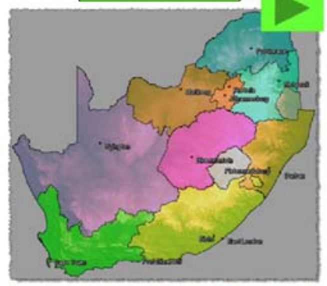

Identify boundaries and distinguish between the areas they enclose on maps
A GIS provides an excellent opportunity to view these boundaries.
Click on the GIS Practise button to work with boundaries.
Click here for ...
GIS Practise
Practise

J

GIS Practise – Boundaries (1)

This page has multiple parts
Click to read next part

- Open the **South African Map** layout from the main MapTrix Geomatica menu
- Turn on the **provincial** boundaries by clicking on the tick
- Click the zoom box icon and zoom in on your province
- Click the zoom in icon to zoom onto the boundary of your province.
- Turn on the **municipal** boundaries for your province and zoom in and out



K

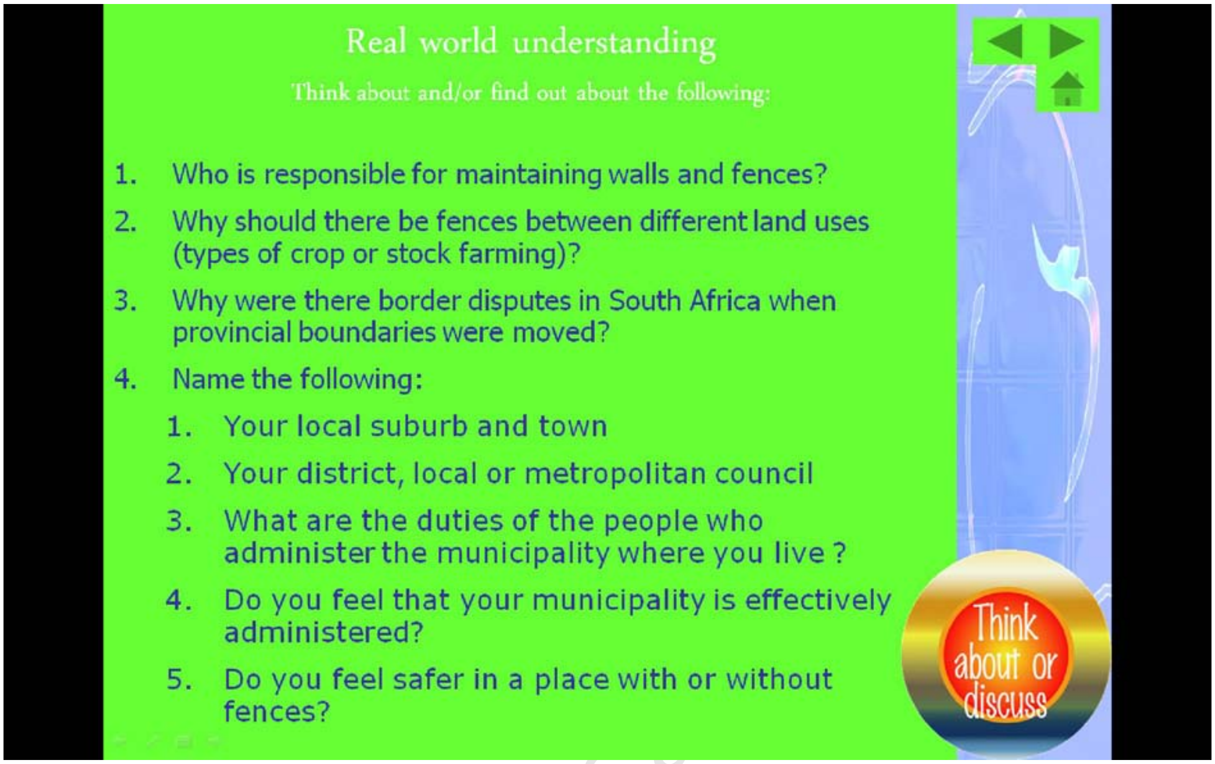
Real world understanding

Think about and/or find out about the following:

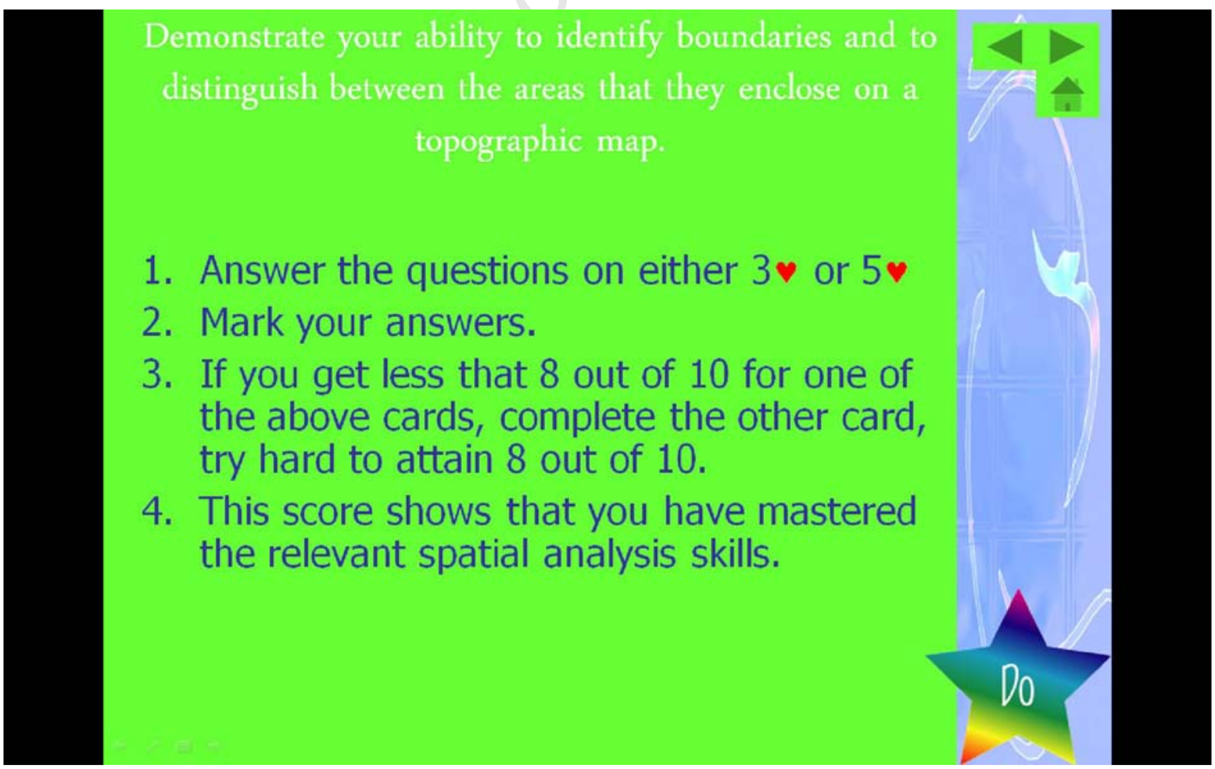
1. What marks the boundary of your school and your home?
2. Inspect the boundary of your school and describe the materials used for the construction of boundary walls or fences.
3. Name the rivers that form boundaries between South Africa and the following countries:
   1. Zimbabwe
   2. Namibia
   3. Lesotho
4. What are the advantages of using natural features such as rivers, mountains or coastlines as boundaries?
5. Why are walls built or fences erected around buildings or properties?

Think about or discuss

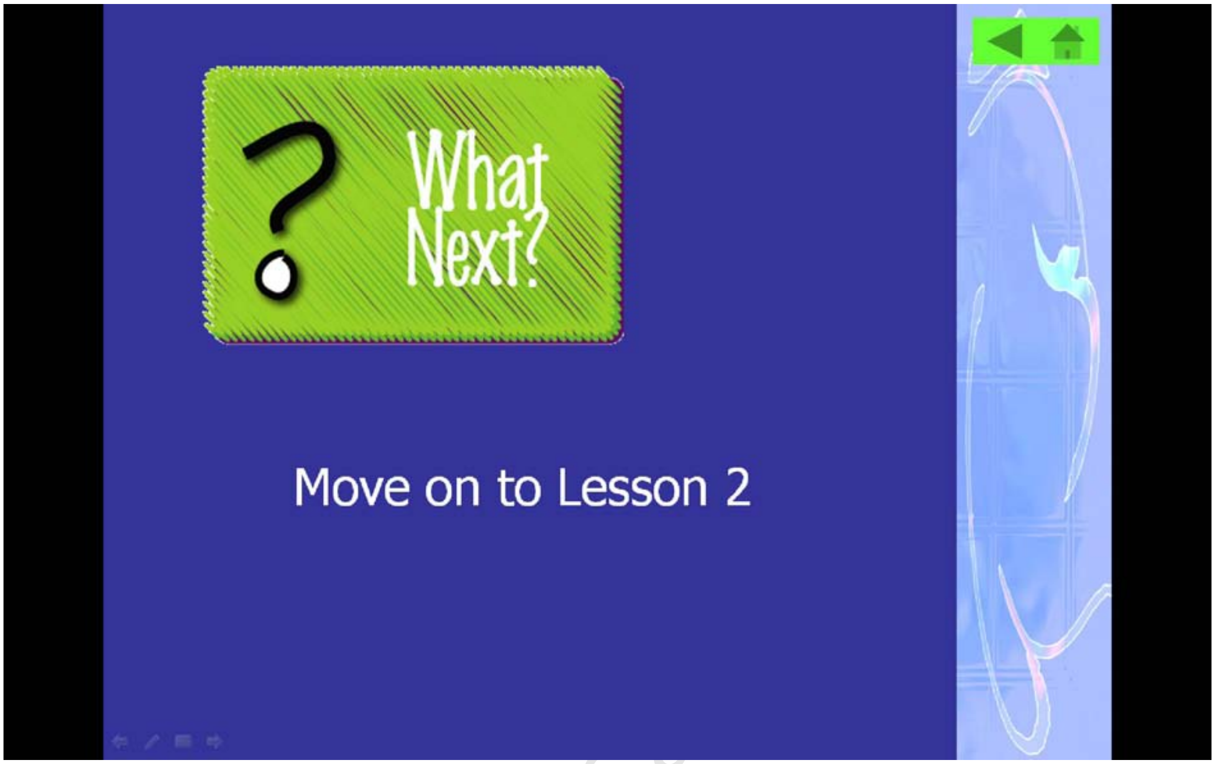
L


Real world understanding
Think about and/or find out about the following:
1. Who is responsible for maintaining walls and fences?
2. Why should there be fences between different land uses (types of crop or stock farming)?
3. Why were there border disputes in South Africa when provincial boundaries were moved?
4. Name the following:
1. Your local suburb and town
2. Your district, local or metropolitan council
3. What are the duties of the people who administer the municipality where you live ?
4. Do you feel that your municipality is effectively administered?
5. Do you feel safer in a place with or without fences?
Think about or discuss

M


Demonstrate your ability to identify boundaries and to distinguish between the areas that they enclose on a topographic map.
1. Answer the questions on either 3♥ or 5♥
2. Mark your answers.
3. If you get less that 8 out of 10 for one of the above cards, complete the other card, try hard to attain 8 out of 10.
4. This score shows that you have mastered the relevant spatial analysis skills.
Do

N



O

Appendix 8.1

TOPOGRAPHIC MAP ANALYSIS COURSE

offered at SCILAB C in R. W. James Building, University of Cape Town, between 2nd and 12th July 2007

PARTICIPANT INFORMATION SHEET

to be completed and returned before a booking can be made. Bookings close on 15 June 2007.
All information that is supplied will be treated with strictest confidence.

Enquiries can be directed to Lorraine Innes 083 702 4003 or lorraine@maptrix.co.za
Completed forms can be delivered to Room 406 Dept of Environmental and Geographical Science, UCT or faxed to 021 761 6886 or posted to P.O. Box 382, Simon's Town, 7995.

Participant's name:	Date of birth:
Contact details: Please give a land line, fax or cell phone number:	
Please give an email or postal address:	

Please tick the appropriate block:	Male:	Female:

School goers please tick the last grade you completed:

Grade 7:	Grade 8:	Grade 9:	Grade 10:	Grade 11:	Grade12:

Post-matriculants please tick the number of years of completed education or training:

1	2	3	4	5	6

Please fill in the following:

What is your home language?		What is your language of schooling?		What other languages do you speak?	

Please tick or enter the examination subjects you plan to offer (or have offered) for matric:

English:	Afrikaans:	Xhosa:	Maths:	Science:	Geography:
History:	Biology	Business Studies:		Computer Studies:	

To be completed by the participant:	
I (full names written clearly):	
undertake to abide by the following rules and guidelines if I am accepted on the course: • to arrive on time for each session that I have booked • to respond honestly to and comment fairly on the learning programme offered • to make every effort to complete the course to the best of my ability • to sit both a pre- and post-test • not to disturb other participants and to respect the property and equipment that will be supplied I understand that my results will be used for research purposes and give permission for them to be included in a research report on condition that my identity will remain confidential.	
Signature:	Date:

To be completed by a parent or guardian of all participants under 18 years of age:	
I (full names written clearly):	
parent/guardian of this participant give permission for him/her to participate in this Topographic Map Analysis Course and for the results to be used in an educational research report.	
Signature:	Date:

Appendix 8.2 (i)

Topographic map analysis course

Opening Questionnaire

NAME ………………………………………………………………………**DATE** ……………………………………

INSTRUCTIONS: Please tick or fill in the boxes below.

How do you feel when using a computer?

Confident	Enjoyment	Interest	Bored	Scared

How often do you use a computer?

every day	every few days	once a week	once a month	very seldom	never

Name the computer programmes you use.

What does GIS stand for?

If you use a computer, where do you use it?

School	Work	Home	An internet cafe
At another venue – please describe			

If you are still at school, is there a computer laboratory at your school?

None	One	Two

If so, approximately how many computers are there?

If you have you ever used the computer laboratory, what subject(s) were you using computers for?

Which of the following do you have difficulty with when using topographic maps? (You may tick one or more.)

Boundaries	Direction	Position	Bearing
Height	Distance and area	Gradient	Profiles
Anything other map use problems?			

Why are you attending this course?

(Please tick for each answer below)	Yes	Not sure	No
I want to get better marks for exercises using maps (mapwork)			
I hate mapwork and I am just trying to pass it			
I want to improve my understanding of maps generally			
I enjoy using maps			
My teacher forced me to come			
My parents encouraged me to come			
I had nothing else to do			
My friend was coming so I came too			
You want to study geography at university			

Appendix 8.2 (ii)

Topographic map analysis course

Opening Questionnaire [version 2]

NAME ……………………………………………………………………**DATE** ……………………………………

INSTRUCTIONS: Please tick or fill in the boxes below.

How do you feel when using a computer?

Confident	Enjoyment	Interest	Bored	Scared

How often do you use a computer?

every day	every few days	once a week	once a month	very seldom	never

Name the computer programmes you use.

What does GIS stand for?

If you use a computer, where do you use it?

School	Work	Home	An internet cafe
At another venue – please describe			

Do you use the computer laboratory at school?

Never	About once a month	About once a week	Every day

If you regularly use the computer laboratory, what subject(s) do you use computers for?

Which of the following do you have difficulty with when using topographic maps? (You may tick one or more.)

Boundaries	Direction	Position	Bearing
Height	Distance and area	Gradient	Profiles
Anything other map use problems?			

What are your feelings about maps?

(Please tick for each answer below)	Yes	Not sure	No
I want to get the best marks I can for exercises using maps (mapwork)			
I hate mapwork			
I don't mind mapwork, I just want to pass it			
I want to improve my general understanding of maps			
The mapwork we do at school is very hard			
I enjoy using maps in and out of school			
I think maps are a waste of time			
I use maps outside of school for travelling and/or orienteering			
I want to study geography at university so need to understand and use maps			
I wish I could do geography without having to do mapwork			
I don't understand maps			
GIS is a new development in IT but I am not interested in GIS or IT			
GIS is great because it is like having maps on computer			

Appendix 8.3 (i)

Topographic map analysis course

Map reading skills assessment - S TEST

NAME ……………………………………………………………………………

DATE ………………………………… **START TIME** ……………………….

INSTRUCTIONS: Please study the MapAware Test Map and answer the 15 questions that follow. Please tick only one correct answer.

EXAMPLE

a. cultivated land	b. orchards ü	c. vineyards	d. open veld

NB: The map does not show a real place.
Accurate map symbols are used to create a landscape.
The terms in the reference list have been used to set and answer the questions

QUESTIONS

1. Name the type of transport feature shown in **black** in E3.

a. other road	b. railway	c. freeway	d. track

2. If you went to stay at Montana (C3-D3) in False Bay, what kind of holiday accommodation would be available?

a. caravan park	b. hotel	c. camp site	d. game reserve

3. Name the feature which starts in E5 and leaves the map area in A2.

a. power lines	b. railway lines	c. fences	d. roads

4. What feature occupies the area between Mowbray Aerodrome (H9-H10) and Salt River Station (H10)?

a. nature reserve	b. open veld	c. vlei	d. vineyards

5. What is shown by the symbol in H6 that is named in unusual lettering (`gothic script`) in H5?

a. lighthouse	b. monument	c. Stoney Point	d. shipwreck (the Seafarer)

6. What kind of construction is indicated along the transport feature in B6?

a. embankment	b. walls	c. fences	d. bridge

7. What kind of boundary goes from the trigonometric station in C13 to the square shaped beacon symbol in C17

a. provincial	b. international	c. game reserve	d. farm

PLEASE TURN OVER

8. How many dams are completely inside block C12?

a. none	b. one	c. two	d. three

9. In which of the following blocks does a non-perennial river occur?

a. J10	b. J14	c. B19	d. E7

10. What features associated exclusively with mining are found in G10?

a. buildings	b. railways	c. pipeline	d. mine dumps

11. From where do the people at Ratsegae (J21) get their water?

a. reservoir	b. water point	c. river	d. dam

12. What height does the darker contour line in H19 indicate?

a. 200 m	b. 220 m	c. 242 m	d. 180 m

13. In which of the following blocks does a dry pan occur?

a. C2	b. A2	c. E21	d. H13

14. Serious soil erosion has occurred near Mentzdam (named in G14). In which block has most erosion occurred?

a. G17	b. H12	c. H17	d. H16

15. Which best describes the kind of farming done at Boschrant (H15)?

a. cultivated land	b. plantation	c. fruit farming under irrigation	d. orchard and vineyard

FINISHING TIME ……………………………………

NUMBER OF MINUTES TAKEN TO DO THE TEST
……………………………

Appendix 8.3 (ii)

Topographic map analysis course

Map reading skills assessment - T TEST

NAME ....

DATE .... START TIME ....

INSTRUCTIONS: Please study the MapAware Test Map and answer the 15 questions that follow. Please tick only one correct answer.

EXAMPLE

a. cultivated land	b. orchards ü	c. vineyards	d. open veld

NB: The map does not show a real place.
Accurate map symbols are used to create a landscape.
The terms in the reference list have been used to set and answer the questions

QUESTIONS

1. Name the type of transport feature shown in **black** in block E16.

a. freeway	b. track	c. railway	d. other road

2. At which special function building identified in F6 will you regularly find large numbers of young people during the day?

a. post office	b. school	c. hotel	d. police station

3. A straight line symbol links D19 and G16. This feature is associated with transporting:

a. water	b. goods in trains	c. goods in trucks	d. electricity

4. What natural feature does the Brinkspruit flow through in J10?

a. perennial pan	b. dam	c. vlei	d. lagoon

5. What is indicated by the symbol in H12 that is named in unusual lettering (gothic script) in H13?

a. monument	b. wind pump	c. church	d. radio tower

6. What kind of construction is indicated along the transport feature in A6?

a. embankment	b. cutting	c. wall	d. bridge

7. What kind of boundary extends from the trigonometrical station in D16 to the edge of the map (J19)?

a. provincial	b. game reserve	c. international	d. farm

PLEASE TURN OVER

8. Name the largest dam in the map area.

a. Tugela	b. Mentz	c. Vaal	d. Monument

9. A confluence is where two rivers join. In which block does a non-perennial tributary join a perennial river?

a. D18	b. F13	c. J14	d. D9

10. Many features associated with mining can be seen in and around F10. Two of these features lie partly **inside** block F10 What are they?

a. two mine dumps	b. two old diggings	c. two slimes dams	d. two excavations

11. A permanent supply of water is available for the buildings near Clewer Station (B6). Where does the water come from?

a. non-perennial stream	b. pipeline	c. reservoir	d. perennial river

12. What height does the contour line in B20 indicate?

a. 261 m	b. 220 m	c. 200 m	d. 240 m

13. In which of the following blocks does a dry water course (sandy river bed) occur?

a. B1	b. B19	c. C2	d. E21

14. Although the Drakensburg is higher, Ntabende (D17) is rockier. Which conventional sign indicates this fact?

a. contour lines	b. trigonometric station	c. prominent rock outcrop	d. erosion

15. The farm Rotsvas (C9) produces grain and not fruit like the surrounding farms. What evidence from the map supports this statement?

a. vineyards	b. cultivated land	c. orchards	d. open veld

FINISHING TIME ……………………………………

NUMBER OF MINUTES TAKEN TO DO THE TEST
……………………………

Appendix 8.3 (iii)

MapAware Test Map (based on the Style Chart of the South African 1:50 000 topographic map and used for map reading S Test and T Test)

Appendix 8.4 (i)

Topographic map analysis course

Map analysis skills assessment - S TEST

NAME ………………………………………………………………………………

DATE ………………………………… **START TIME** ……………...………

INSTRUCTIONS:
Please study the Cape Town map extract and answer the 10 questions that follow.
Write your answers in the spaces provided.
Answers must include a unit of measurement where appropriate.
All construction lines must be done on the photocopy of the full colour map provided.

QUESTIONS

1. In G8, there are three line symbols parallel to each other along the boundary of a conservation area. The thin black line is a fence; name the two green symbols.

		2

2. You are standing on Signal Hill (C2) where four original farm boundaries meet. Name the directions that the three straight boundaries follow away from the hill.

			3

3. Name the kind of station you would find at 33°58'12"S; 18°27'0"E and name the area that it serves.

		2

4. Along what true bearing would a helicopter pilot fly after collecting water from the middle of Newlands Reservoir (J8) for a fire at the top of Plumpudding Hill (G8)?

North line constructed?	Places joined?		3

5. If you were walking along the contour path, heading northwest after crossing Platteklipstroom (H3), what contour would you be following?

	2

6. What is the difference in altitude between the end of the access road to Rhodes Memorial (H9) and Kings Block House (G8)? (Show workings)

Top of slope:	Bottom of slope:	Difference:	4

PLEASE TURN OVER

7. How far, in metres, is Kings Block House (G8) from Rhodes Memorial (H9)?

	2

8. Calculate the gradient of the slope that visitors climb between the national monuments mentioned in Questions 6 and 7?

(.........................) : (...........................) = 1:	2

9. What is the size in km² of the northern half of the map?

Length	Breadth	Area	
			4

10. Draw a line on the photocopied map between the highest points on Signal Hill (C2) and Devil's Peak (H6). Use the framework below to sketch a profile between these points. Then select the statement below that correctly describes the shape of the profile from northwest to southeast.

a. Gentle, slightly concave, west facing slope; rounded convex summit; steep concave slope down to the valley floor.
b. Steep, southeast facing slope; wide concave summit; steep, northwest facing slope.
c. Gentle, southeast facing slope; wide valley floor; convex northwest facing slope up to a summit which is almost twice as high as the opposite end of profile.
d. Gentle even slope down from high, rugged peak, across plateau to a low hill.

[framework with heights added manually before copying]	4
	2

Total (30)

FINISHING TIME ……………………………………

NUMBER OF MINUTES TAKEN TO DO THE TEST ………………

Appendix 8.4 (ii)

Topographic map analysis course

Map analysis skills assessment - T TEST

NAME ……………………………………………………………………………….

DATE ………………………………….. START TIME ……………...………

INSTRUCTIONS:
Please study the Cape Town map extract and answer the 10 questions that follow.
Write your answers in the spaces provided.
Answers must include a unit of measurement where appropriate.
All construction lines must be done on the photocopy of the full colour map provided.

QUESTIONS

1. A broad green line and a thin black line are used for boundaries of both nature reserves and forests. Name both areas on the map enclosed by this kind of boundary. Give the smallest one first. (Hint: study the southern edge of the map.)

		2

2. You are standing on Devil's Peak (H6) where four boundary lines meet. Name the directions away from the peak of: the two sections of nature reserve boundary and the short section of original farm boundary.

			3

3. Name the kind of station you would find at 33°56'15"S; 18°28'20"E and name the suburb that it serves.

		2

4. Along what true bearing would a helicopter pilot fly after collecting water from the middle of Mocke Reservoir (G1) for a fire at Devil's Peak forest station (F7)?

North line constructed?	Places joined?		3

5. You were walking along the path that follows a contour line in G9 and looking down on Groote Schuur Hospital. How high are you above sea level?

	2

6. What is the difference in altitude between the Upper Station of the cableway (at the top apex of the trig beacon symbol in H2) and the Lower Station (G2)? (Show your workings.)

Top of slope:	Bottom of slope:	Difference:	4

PLEASE TURN OVER

7. How far apart, in metres, are the Upper (H2) and Lower Stations (G2) of the cableway?

	2

8. Calculate the gradient of the slope between the Upper (H2) and Lower Stations (G2) of the cableway.

(.........................) : (...........................) = 1:	2

9. What is the size in km² of the northern half of the map?

Length	Breadth	Area	
			4

10. Draw a line on the photocopied map between the highest point on Devil's Peak (H6), through trig beacon number 500 on the University of Cape Town campus, to the edge of the map. Use the framework below to sketch a profile along this line. Then select the statement below that correctly describes the shape of the profile from west to east.

a. Gentle, southeast facing slope down onto a wide valley floor

b. Convex east facing slope, which is twice as high as the opposite end of the profile on a flat plateau.

c. Steep, east facing concave slope which levels out almost down to sea level.

d. Gentle even slope down from a high, rugged peak then goes across a plain.

[framework with heights added manually before copying]	4
	2

Total (30)

FINISHING TIME ....

NUMBER OF MINUTES TAKEN TO DO THE TEST ....

Clubs 2

Bearing — Upington (28° 24' S; 21° 12' E)

1	Two railways enter the map area from the west. When driving a train into the map area on the southernmost of these two railway lines, what bearing is the train driver following?
2	When driving a train past Updustria heading southeast on the main line, what bearing is the train driver following?
3	The two railways from the west converge at a benchmark at 816,1 m. What is the bearing of the railway as it heads towards Upington from this point?
4	John is cycling back to town after an early morning ride with the sun shining full on his back. As he enters the map area on the access road parallel to the power line, what is his bearing?
5	A truck driver leaves Upington on the R32 arterial route heading north. Just outside town the route makes a sharp left turn. What bearing does he follow [a] before the turn and [b] after the turn?
6	A light aircraft is approaching Sir Pierre van Ryneveld airport [lughawe] from the southwest. What is the pilot's bearing when his wheels touch down on the narrow runway?
7	An aircraft flies low over the Orange River as it approaches Sir Pierre van Ryneveld airport. As it touches down at the end of the longest runway, what is the pilot's heading [bearing]?
8	Match the following recreation or sports facilities with their bearings from Upington station. [a] race track, [b] sports fields [recreation area], [c] shooting range [skietbaan] [i] 248° [ii] 330° [iii] 53°
9	This area is very flat. There is only one trig beacon near the centre of the map. You are looking out of the window at the police station in Pabalello. At what bearing can you see the communication tower near the trig beacon?
10	There is a foot bridge over the Orange River. It has been built parallel to the bridge carrying the R32 and R64 arterial routes. If you stand at the southeast end of the foot bridge, what unusual historical monument will you see close by at a bearing of 45°?

Appendix 8.6 (i)

Topographic map analysis course

Closing Questionnaire

NAME ……………………………………………………………………**DATE** ………………………………………

INSTRUCTIONS: Please tick or fill in the boxes below.

1. How do you feel about using a computer now that you have finished this course?

Confident	Enjoyment	Interest	Bored	Scared

While working through the lesson on:	I worked alone				When not working alone, I was helped by the teacher		When not working alone, I was helped by a friend	
	yes, all the time	>½ the time	<½ the time	none of the time	a little	a lot	a little	a lot
Boundaries								
Direction								
Position								
Bearing								
Height								
Distance and area								
Gradient								
Profiles								

When working with a friend, I worked out the answer

all the time	>½ the time	<½ the time	none of the time

When working with a friend, he/she worked out the answer

all the time	>½ the time	<½ the time	none of the time

Were the following components of each lesson:	useful all the time	useful >½ the time	useful <½ the time	useful none of the time	comments
Lesson text					
Animated illustrations					
Glossary					
GIS lesson					
GIS practice					
Maths lesson					
Voice-over (sound)					
Movies					

What advantages does a GIS have over a paper map?

Would you like to know more about GIS?

Do you think that learning map analysis skills is better with GIS or without? Why?

Which lesson was the hardest to learn? Why?

Which lesson was the easiest to learn? Why?

In the opening questionnaire you listed the things you were having difficulty with. Did this programme help to improve those skills? Explain

The objective of this programme is to improve map analysis skills. Did it meet this objective?

How could the programme be improved? Please explain or comment

General

Things that could be left out?

Things that could be included?

Appendix 8.6 (ii)

Topographic map analysis course

Closing Questionnaire [version 2]

NAME ……………………………………………………………………**DATE** ……………………………………

INSTRUCTIONS: Please tick or fill in the boxes below.

How do you feel about using a computer to learn map skills now that you have finished this course?

Confident	Enjoyment	Interest	Bored	Scared

MapTrix Geomatica is designed to be a self-instruction programme. Please indicate how much of the time you worked alone, with a friend or with a teacher:

While working through the lesson on:	I worked alone				When not working alone, I was helped by the teacher		When not working alone, I was helped by a friend	
	all the time	>½ the time	<½ the time	none of the time	a little	a lot	a little	a lot
Boundaries								
Direction								
Position								
Bearing								
Height								
Distance and area								
Gradient								
Profiles								

When working with a friend, I worked out the answer

all the time	>½ the time	<½ the time	none of the time

After reading each question, I did the following:	all the time	>½ the time	<½ the time	none of the time
worked out the answer from the map				
guessed the answer				
asked a friend				
copied the answer				

I would like to have been able to mark my answers.

No	Yes
If not, Why not?	Why?

Did you use every GIS lesson for each topic?

No	Yes
If not, Why not?	Why were the GIS lessons useful?

Were the following components of each lesson:	useful all the time	useful >½ the time	useful <½ the time	useful none of the time	comments
Lesson text					
Animated illustrations					
Glossary					
GIS lesson					
GIS practice					
Maths lesson					
Voice-over (sound)					
Movies					

What general advantages does a GIS have over a paper map?

Would you like to know more about GIS?

Do you think that learning map analysis skills is better with GIS or without? Why?

Which lesson was the hardest to learn? Why?

Which lesson was the easiest to learn? Why?

In the opening questionnaire you listed the things you were having difficulty with. Did this programme help to improve those skills? Explain

The objective of this programme is to improve map analysis skills. Did it meet this objective?

Write down at least 5 words you would use to describe MapTrix Geomatica to a friend who has not attended the course or write you own general comments.

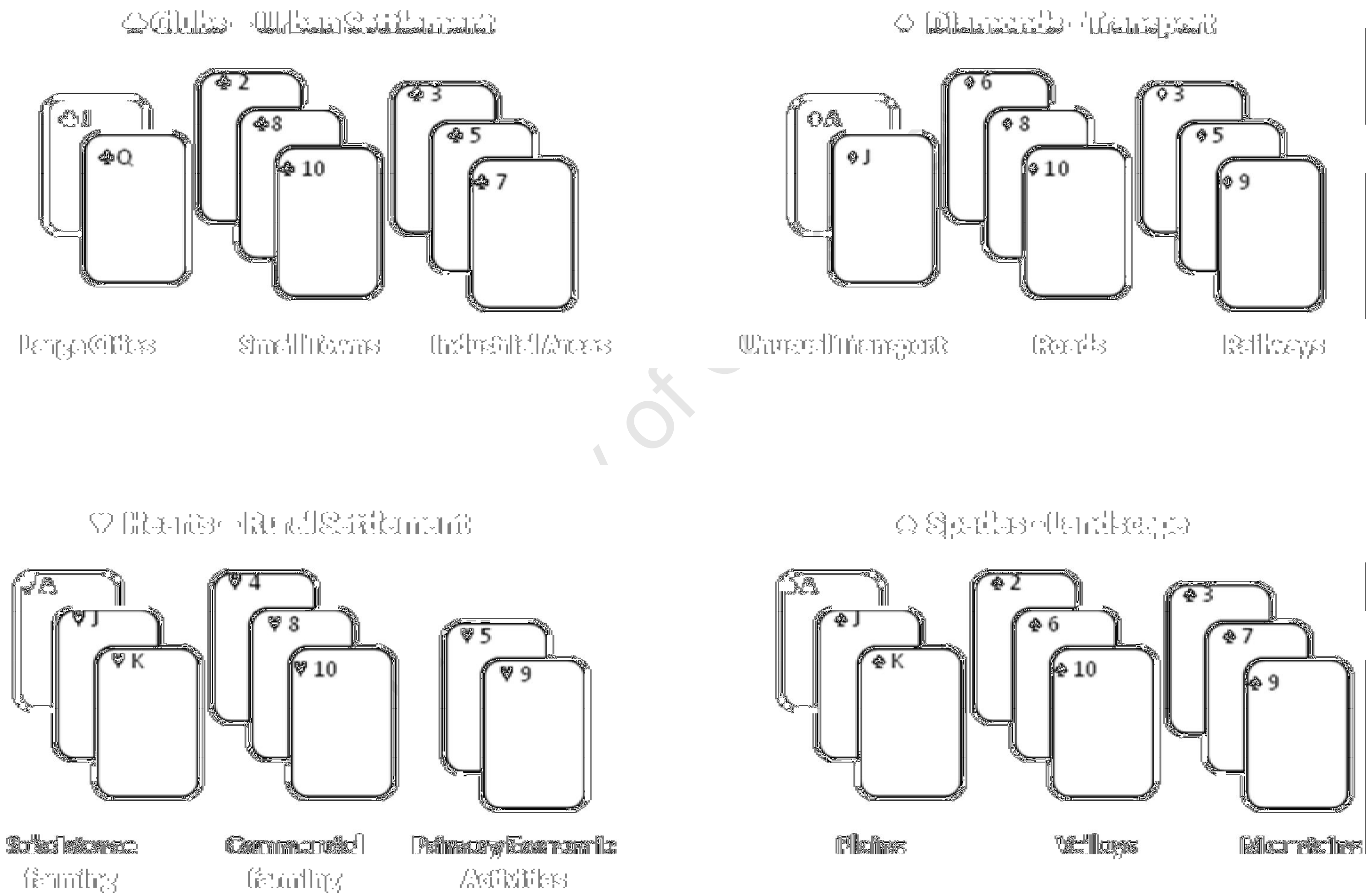
What things do you think could be left out of the programme?

What things do you think should be included?

Appendix 8.7

♧♡♤◇ The MapTrix Digital Game ♧♡♤◇

Select one card from each group



Appendix 8.8

DATA COLLECTION PROCEDURE

The procedure followed to gather the data from the collection instruments is described in this Appendix. (Read in conjunction with Appendices 8.1 to 8.6.)

Appendix 8.1 Participant information form

The participant information sheet was compiled to gather biographical data about the participants. The *headings and/or questions* are in italics in the following discussion. It was completed by the majority of participants. For those who had neglected to hand in the form, relevant information was gleaned directly from their schools where possible.

- *Participant's name and gender*

To preserve anonymity, each name was recorded as a letter and number code (e.g. B16). The letter designated the venue (unrelated to the Group code). The number related to the participant's surname listed in alphabetical order per venue. The numbering was continuous for the total sample population. Gender was entered as 1 = male and 2 = female.

- *Date of birth*

This was used to calculate the age of the participant at the date when they started the trial. Age was recorded in years or part thereof.

- *What is your home language?*

The following codes were allocated based on the range of languages recorded by participants:

1 = English	2 = isiXhosa (a local traditional African language)	3 = Afrikaans (local colonial language derived mainly from Dutch and French)	4 = Other European language	5 = Combination of English and Afrikaans

- *What other languages do you speak*?

The same codes as above were used with the addition of 0 = none.

- *Please tick or enter the subjects you plan to offer for your final examinations*

Ten of the most popular school subjects were listed for participants to tick and a blank space was available for adding any subjects not listed. Only Geography, Maths, Science and IT were recorded for investigation. Computer studies (Information Technology) was recorded individually as 1 = Yes and 0 = No. Both Mathematical literacy and Mathematics were recorded as Maths. Geography, Maths and Science combinations were coded as follows:

Geography	Maths	Science	Code
1	0	0	1
1	1	0	2
1	1	1	3
0	1	0	4
0	0	1	5
0	1	1	6
0	0	0	7
1	0	1	8

Appendix 8.2 Opening questionnaire

The majority of participants completed an opening questionnaire which had been compiled using the piloting strategy discussed in Chapter Three for the *MapTrix* Survey. The questionnaire was used to assess participants' attitudes to computers, maps and GIS. *(Questions and statements quoted from the questionnaire are in italics)*.

- *How do you feel when using a computer?*

Participants were asked to tick one of the following responses, which were recorded using the code indicated.

5 = Confident	4 = Enjoyment	3 = Interested	2 = Bored	1 = Scared

- *How often do you use a computer?*

Participants were asked to tick one of the following responses, which were recorded using the code indicated.

6 = every day	5 = every few days	4 = once a week	3 = once a month	2 = very seldom	1 = never

- *What does GIS stand for?*

The response required was Geographic Information System (or Science). Answers were coded as follows:

1 = correct answer	0.5 = partially correct answer	0 = incorrect answer	Blank = no response

- *If you use a computer, where do you use it?*

The options offered for ticking or free response are:

School	Work	Home	An internet cafe
At another venue – please describe			

The responses were collapsed into the three given most frequently and coded as follows:

School	Home	Elsewhere	Code
1	0	0	1
1	1	0	2
1	1	1	3
0	1	0	4
0	0	1	5
0	1	1	6
0	0	0	7
1	0	1	8

- *Do you use the computer laboratory at school?*

Learners were given the options below. Their responses were recorded as a code representing the number of days per month that they used the computer laboratory.

0 = Never	1 = About once a month	4 = About once a week	30 = Every day

- *If you regularly use the computer laboratory, what subject(s) do you use the computers for?*

This question was included to find out about the computer laboratory use amongst learners who do not take computer studies. The subjects of most interest for the current research are Geography, Mathematics and Science. A variety of subjects were mentioned but too seldom by too few to establish a pattern so the responses for Maths and Geography have been coded as follows:

Geography	Maths	Other	Code
1	0	0	1
1	1	0	2
1	1	1	3
0	1	0	4
0	0	1	5
0	1	1	6
1	0	1	7
Computer studies (IT) only			0

(As it was established that all participating schools had a computer laboratory, a blank space was used on the spreadsheet to indicate that learners did not use it. Those who took computer studies (IT) as a subject indicated that they used the laboratory very often but as these participants had already been identified their responses were coded zero.)

- *Which of the following do you have difficulty with when using topographic maps? (You may tick one or more.)*

Each potential problem area that was ticked was recorded individually as 1 = Yes and 0 = No. Very few added a free response about map use problems so this was ignored.

Boundaries	Direction	Position	Bearing
Height	Distance and area	Gradient	Profiles
Any other map use problems?			

- *What are your feelings about maps?*

To evaluate participants' attitudes the items in Table A8.8.1 were used. They contain statements about maps, GIS and studying geography after school. Ticking the appropriate column elicited a measurable response. In some cases a *Yes* response was worth 2 points and a *No* was worth 0. In other cases a *No* response was worth 2 points and a *Yes* worth 0. Because a *Not sure* response is not positive or negative it was allocated 1 point.

Three data items were extracted from Table A8.8.1.

i) A score for the participants' attitudes to maps was calculated as the sum of the response scores in Table A8.8.1(a). A maximum positive attitude earns a score of 20, a neutral attitude is 10 and a maximum negative attitude earns a 0 score.

Table A8.8.1(a) Attitude rating instrument used in the Opening Questionnaire during MapTrix Digital Game and MapTrix Geomatica trials

(Please tick for each answer below)	Yes (agree)	Not sure	No (disagree)
**I want to get the best marks I can for exercises using maps*	2	1	0
**I hate mapwork*	0	1	2
**I don't mind mapwork, I just want to pass it*	2	1	0
**I want to improve my general understanding of maps*	2	1	0
The mapwork we do at school is very hard	0	1	2
**I enjoy using maps in and out of school*	2	1	0
I think maps are a waste of time	0	1	2
I use maps outside of school for travelling and/or orienteering	2	1	0
I wish I could do geography without having to do mapwork	0	1	2
I don't understand maps	0	1	2

(For the Groups SV and SS, only half the above statements were used. For these two Groups, the scores for the five *statements were doubled to get an attitude rating score out of 20.)

ii) Only two statements were included that sought to assess whether participants had a positive or negative attitude to GIS. The attitude rating ranges from 4 to indicate very positive, down to 0 for a negative attitude to GIS.

Table A8.8.1(b) Attitude rating instrument used in the Opening Questionnaire during MapTrix Digital Game and MapTrix Geomatica trials

(Please tick for each answer below)	Yes (agree)	Not sure	No (disagree)
GIS is a new development in IT but I am not interested in GIS or IT	0	1	2
GIS is great because it is like having maps on computer	2	1	0

(For Groups SV and SS there were no statements about GIS)

iii) To assess whether participants had a long term interest in geography, response to the following statement was recorded (but did not form part of the attitude rating score).

Table A8.8.1(c) Attitude rating instrument used in the Opening Questionnaire during MapTrix Digital Game and MapTrix Geomatica trials

(Please tick for each answer below)	Yes (agree)	Not sure	No (disagree)
I want to study geography at university so need to understand and use maps	2	1	0

Appendices 8.3 and 8.4 Map reading and map analysis pre- and post tests

As mentioned when discussing the evaluation process (Figure 7.3), two banks of equivalent difficulty map reading tests (labelled S and T tests in Appendix 8.3) and map analysis tests (labelled S and T tests in Appendix 8.4) were devised and administered alternatively as pre- and post-tests. The score for each answer was entered and added to get a total score out of 15 for map reading and out of 30 for map analysis per participant. These scores for each question were entered for each participant so that the S and T tests could be evaluated for equivalence. Participants were allowed as much time as they required to complete the tests. They were instructed to enter their start and end times which were subtracted to get the time taken to complete each test (in minutes). Post-test times were subtracted from pre-test times to assess whether learners became more proficient (faster) at map reading and at map analysis.

Appendix 8.5 MapTrix Geomatica exercise and answer sheets

Probably the most important data sets required for assessing the efficacy of the map analysis learning programme came from the MapTrix Geomatica exercise and answer sheets. Unfortunately, the map reading performance of Group SX was too weak for them to proceed to the map analysis programme. Although the exercises were available on screen, participants were given hard copy exercise sheets with answer spaces to facilitate gathering the data. They assessed their answers from the model answers on screen. Each correct answer scored 1, partially correct answer scored 0.5 and wrong answer scored 0. The scores for each answer and the totals for the exercises (out of a possible total of 10) were entered for Groups SV, SS, PB and PI (as per Figure 7.5).

Appendix 8.6 Closing questionnaire

Once they had completed the programme and the post-tests, participants were asked to complete a closing questionnaire to assess their response to the programme. As for the discussion of the opening questionnaire, quoted sections are in italics in the following.

- *How do you feel about using a computer (now that you have finished)?*

The first phrase is a repeat of the first question in the opening questionnaire, used to assess whether attitude to using a computer had changed while trialling the programmes. Participants ticked one of the following responses, which were recorded using the code indicated.

5 = Confident	4 = Enjoyment	3 = Interested	2 = Bored	1 = Scared

- *MapTrix Geomatica is designed to be a self-instruction programme. Please indicate how much of the time you worked alone, with a friend or with a teacher*

Responses were coded as indicated. In cases where participants indicated that they worked both alone and with a teacher or friend, their responses were adjusted from observations of their strategies.

While working through the lesson on:	*I worked alone*				*When not working alone, I was helped by the teacher:*		*When not working alone, I was helped by a friend:*	
	all the time.	*>½ the time.*	*<½ the time.*	*none of the time.*	*a little*	*a lot*	*a little*	*a lot*
Boundaries	4	3	1	0	1	2	1	2
Direction	4	3	1	0	1	2	1	2
Position	4	3	1	0	1	2	1	2
Bearing	4	3	1	0	1	2	1	2
Height	4	3	1	0	1	2	1	2
Distance and area	4	3	1	0	1	2	1	2
Gradient	4	3	1	0	1	2	1	2
Profiles	4	3	1	0	1	2	1	2

- *When working with a friend, I worked out the answer*

Responses were coded as follows:

4 = *all the time*	3 = *>½ the time*	1 = *<½ the time*	0 = *none of the time*

The section in Table A8.8.2 was added for Groups PB and PI to ascertain learners' preferred strategies when working through the exercises. In cases where participants indicated both that they employed a strategy all the time and used others as well, their responses were adjusted from observations during the trial.

Table A8.8.2 Preferred question answering strategies

***After reading each question, I did the following:**	***all the time***	***>½ the time***	***<½ the time***	***none of the time***
A. worked out the answer from the map	4	3	1	0
B. guessed the answer	4	3	1	0
C. asked a friend	4	3	1	0
D. copied the answer	4	3	1	0

*Groups SV and SS (the first two groups) were not presented with this table in their closing questionnaires.

An additional code was generated from the observation of Groups SV and SS which included participants who consistently used the answers as a guide before writing down their own answers. See Strategy E.

E. worked backwards from the given answer	4	3	1	0

In order to correlate both exercise and pre- and post-test scores with learning strategies, a further single code was generated to indicate the most preferred strategy over all. This was derived from responses to the last three questions as well as observations and interviews. The preferred strategy was coded as follows:

0 = Strategy A	1 = Strategy B	2 = Strategy C	3 = Strategy D	4 = Strategy E

- *I like to mark my answers* (or for Group PB *I would like to have been able to mark my answers*)

The majority of participants marked their own answers (except Group PB). The slight variation of the format of the opening statement made it possible to rate all responses the same way. Free responses were evaluated, grouped into 5 categories and coded as follows:

No	*Yes*
If not, Why not? 1 = Teacher should mark answers 2 = I might/would cheat	*Why?* 3 = Positive reinforcement 4 = Learn from mistakes 5 = Other

- *Did you use every GIS lesson for each topic?*

Free responses were evaluated, grouped into 5 categories and coded as follows:

No	*Yes*
If not, Why not? 1 = Did not need (every GIS lesson) 2 = Technical difficulties (with software or hardware)	*Why were the GIS lessons useful?* 3 = Explained GIS 4 = Helped answer questions 5 = Taught how to use maps

- *Were the following components of each lesson (useful)*

Responses were coded for each component individually as follows:

	useful all the time?	*useful >½ the time?*	*useful <½ the time?*	*useful none of the time?*
Lesson text	4	3	1	0
Animated illustrations	4	3	1	0
Glossary	4	3	1	0
GIS lesson	4	3	1	0
GIS practice	4	3	1	0
Maths lesson	4	3	1	0
Voice-over (sound)	4	3	1	0
Movies	4	3	1	0

- *What general advantages does a GIS have over a paper map?*

Most participants were able to give at least two advantages. Responses were evaluated, grouped and coded as follows:

1 = Quick, fast or effective 2 = Easier to understand 3 = Zoom function (see greater detail)	4 = Interactive, fun, exciting, interesting. 5 = More accurate 6 = No advantages 7 = Other advantages

- *Would you like to know more about GIS?*

Responses coded as follows:

1 = Yes	2 = Undecided	3 = No

- *Do you think that learning map analysis skills is better with GIS or without? Why?*

A wide range of free responses were evaluated, grouped and coded as follows:

Learning is better with GIS	Undecided	Learning is better without GIS
1 = IT is relevant in all subjects/everything 2 = GIS improves understanding of maps 3 = GIS is a good learning 'tool'	4 = Use both 5 = Not sure	6 = There are no computers in exam rooms 7 = IT problems are a distraction 8 = Prefer paper maps

- *Which lesson was the hardest to learn? Why? Which lesson was the easiest to learn? Why?*

While most participants indicated the hardest and easiest lessons, very few indicated why they had made their choices. Points were awarded according to the lessons selected and no further information was added. The eight lessons were evaluated according to the highest number of 'votes' in each category.

- *In the opening questionnaire you listed the things you were having difficulty with. Did this programme help to improve those skills? Explain*

As with section 8.8.11, few explanations were offered. Responses were coded as follows:

1 = Yes	2 = Undecided	3 = No

- *The objective of this programme is to improve map analysis skills. Did it meet this objective?*

Responses were coded as follows:

1 = Yes	2 = Undecided	3 = No

- *Write down at least 5 words you would use to describe MapTrix Geomatica to a friend who has not attended the course or write your own general comments*

An attitude rating score was generated as a means to quantify the participants' response to the programme. The rating score was based on their free responses. The words and phrases used by the last trial group were listed and annotated using *D* = description, ü = positive and û= negative, these were then transferred to a table. As each groups' attitudes were recorded, the descriptions that participants used were added to the columns in the table. The table was later revisited and further annotated so that ý = very negative and þ = very positive. Values were allocated to each group of words (see the last row in Table A8.8.3).

Table A8.8.3 Attitude rating score derived from free responses

Response	**Very negative**	**Negative**	**Descriptive/neutral**	**Positive**	**Very positive**
Symbol	ý	û	*D*	ü	þ
Examples of words used	tedious, frustrating,	boring, long, tiring,	self-study, self-help,	easy, useful, interesting, detailed, informative, fun.	efficient, interactive, enjoyable, intriguing, clever.
Examples of phrases used		time consuming; hard work	mapwork course; computerised mapwork programme;	how to use maps properly;	valuable learning experience;
Score	-3	-2	1	+2	+3

The attitude rating score for each participant was calculated as the sum of the values allocated to the words they used to describe the programme. 0 was used to indicate no entry in a category. The maximum possible negative attitude earned a score of -15 (5 very negative comments). The maximum possible positive attitude earned a score of +15 (5 very positive comments); a score of 5 indicates a neutral attitude.

- *What things do you think could be left out of the programme?*
- *What things do you think should be included?*

Many respondents left this section blank or indicated 'nothing' to add or leave out. The few responses have been evaluated, grouped and coded as follows:

1 = nothing	2 = movies	3 = other technical issues	4 = content issues	5 = other

1 000		1 000
900		900
800		800
700		700
600		600
500		500
400		400
300		300
200		200
100		100
0		0

Vertical Scale = 1 cm represents 200 m

Statement::	2

1 000		1 000
900		900
800		800
700		700
600		600
500		500
400		400
300		300
200		200
100		100
0		0

Vertical Scale = 1 cm represents 200 m

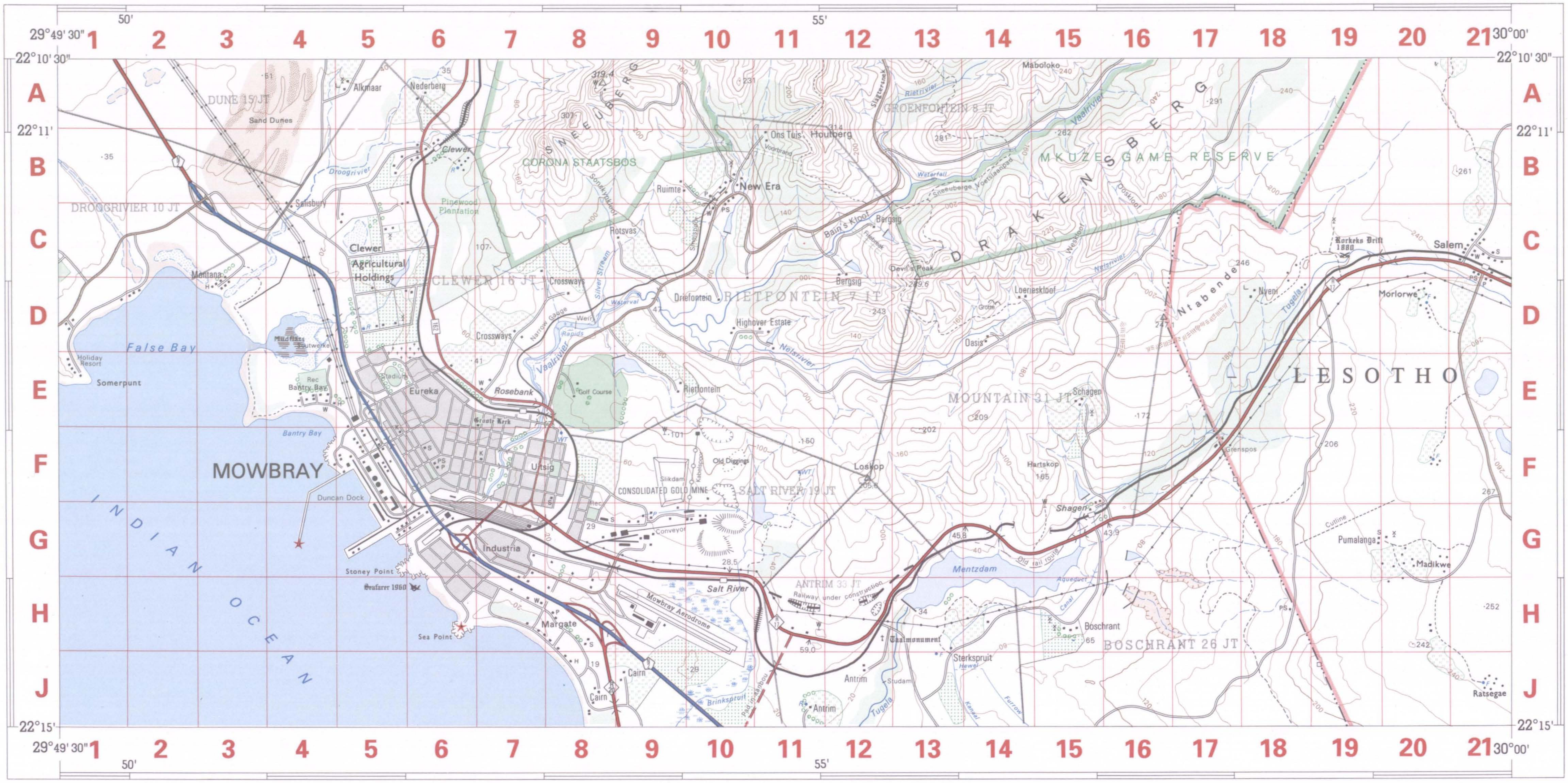
Statement:	2

mapaware test map

SA 1:50 000

extract from Mowbray Style Chart for 1:50 000 Topographic Map Series

PUBLISHED BY THE CHIEF DIRECTORATE OF SURVEYS AND MAPPING



Metres 1000 0 1 2 3 4 5 6 7 8 9 10 Kilometres

CONTOUR INTERVAL 20 METRES

REFERENCE

- National Freeway; National Route
- Arterial Route
- Main Road
- Secondary Road; Bench Mark
- Other Road; Bridge
- Track and Hiking Trail
- Railway; Station or Siding
- Other Railway; Tunnel
- Embankment; Cutting
- Power Line
- Built-up Area
- Buildings; Ruin
- Post Office; Police Station; Store
- Place of Worship; School; Hotel
- Fence; Wall
- Windpump;Monument
- Communication Tower
- Mine Dump; Excavation
- Trigonometrical Station; Marine Beacon
- Lighthouse and Marine Light
- Cemetery; Grave

True N.

Mag. N.

Mean magnetic declination 15°12' West of True North (July 1995).
Mean annual change 3' Westwards (1995 - 2000).
Supplied by Hermanus Magnetic Observatory.

Cadastral information supplied by the Surveyor-General
Original Farms

REFERENCE

- International Boundary and Beacon
- Provincial Boundary
- Protected Area
- Perennial River
- Perennial Water
- Non-perennial River
- Non-perennial Water
- Dry Water Course
- Dry Pan
- Marsh and Vlei
- Pipeline (above ground)
- Water Tower; Reservoir; Water Point
- Coastal Rocks
- Prominent Rock Outcrop
- Erosion; Sand
- Woodland
- Cultivated Land
- Orchard or Vineyard
- Recreation Ground
- Row of Trees

Appendix 9.1

MAPTRIX GEOMATICA PROTOTYPE - PRODUCT REPORT

When running the first trial at UCT between 2 and 12 July, with the 23 participants in Groups SV and SS, a number of problems were identified by the researcher and assistants. Initially it was proposed that these should be corrected before the school trials were undertaken but this was not possible. On occasion, these errors became instruction opportunities and also a cross-check on whether participants were cheating by copying answers rather than working them out.

General comments arising from the first trial

The technical assistant (Banele Dube) noted that the programme created *loc* files when participants closed screens rather than switching from one screen to another. When this happened repeatedly the programme froze and had to be restarted. Participants were coached in the use of the hyperlink button to prevent this problem.

There was a mismatch between the version of the movie player used to produce the video clips and that most easily available to download off the internet. The codex did not match and the correct version of the codex had to be sourced and down loaded onto some of the PC's in the computer laboratory during the first trial and then onto some laptops in subsequent trials. This proved inconvenient and because not all participants were working at the same pace, the problem was not immediately evident and often held up progress for participants, many of whom chose to ignore the movie clips rather than struggle to get them to play.

Opening Lesson Screen

- Lesson 1. Boundaries - title should be task related e.g. Find Boundaries (has no activation button)
- Lesson 2. Direction – title is too long and learners are offered the chance to 'select' the lesson when there is only one lesson
- Order of the active lesson buttons does not match the order of the lessons

Lesson 1 Boundaries

- Glossary – spatial information (return key not working properly)
- Problem exiting glossary page without clicking anywhere on screen
- No exit key on the "what next" page, it loops back

Maths sub-lesson (required for Lesson 1)

- A number of mathematics related questions were asked of the researcher and assistants. Many participants did not understand the terminology relating to shapes. Although the terms are explained in the glossary, an illustrated lesson on shapes is required because learners were not familiar with terms like radius, diameter, perimeter etc

Lesson 2 Direction

- The map extracts from topographic map sheets Benoni 2628AB and Johannesburg 2628AA are not the most recent editions and must be replaced by extracts from sheets of the 6th edition dated 2002.

Lesson 6 Distance and area

- No active button for the lesson on the opening screen – this is a problem because there are 3 lessons but only 2 have active buttons
- Calculation on word scale example is incorrect. It should be 12.5 x 4 = 50 km (not 100 km)
- Distance video clip - the scale box must be highlighted. Format must be consistent e.g. 1:50 000 not 1:50,000

Maths sub-lesson (included in Lesson 6)

- Examples alternate between maps at 1:50 000 and 1:10 000. This may be confusing as only topographic maps are used in the exercises (suggest moving 1:10 000 examples to the advanced version).
- The area of a rectangle has been calculated incorrectly; step 4 should be 400 x 200 m = 80 000 m² = 8ha.
- The navigation buttons at the end of the Maths (and GIS) sub-lessons do not return to the main lesson.

GIS sub-lesson F (part of Lesson 6 on Distance and Area)

- The units of measurement are inconsistent
- The icon buttons are active but they link to the next GIS lesson
- Measuring shape using the GIS tools needs a voice-over as this had to be explained repeatedly

GIS practice included in Lesson 6

- The GIS practice button was not active alongside the relevant instruction to “Perform various map analysis tasks related to distance and area” and could only be accessed via the GIS lesson screen.
- The area measurement exercise is based on the Port Elizabeth map extract which is not included in the map selection for the MapTrix Geomatica prototype. This made navigation difficult and required repeated intervention from the researcher and technical assistant.

Lesson 7 Gradient

- Start of lesson can only be activated by forward arrow on keyboard – mouse click does not work.
- Practical gradient illustration, Example 1 - no sound prompt appears on screen for the voice-over (e.g. put earphones on or turn up volume)
- Incorrect map extract appears. Bourke’s Luck map must be moved to Spades 10 and Skukuza must be used for exercise on Spades 2.
- The eastern edge of the Skukuza map extract has been cropped by 30" and must be restored to its full extent

Lesson 8 Profiles

- Button for glossary item 'What is a profile?' is not active
- There are no navigation buttons to get to the profile example

GIS sub-lesson H – Profiles in a GIS (2) (in Lesson 8)

- When clicking the lesson icon, the screen goes directly to the glossary
- This lesson text requires a voice-over as it deals with a number of steps plus new and therefore difficult content and concepts.
- The lesson text and video clip must include the instruction to turn off the sun-shaded DEM.
- In the video-clip the action of drawing the profile is backwards (i.e. right to left) when compared to the voice-over which gives the instruction from left to right. This is confusing.
- Map of Blyderivierspoort, used for Example 1, has a white patch
- In Example 2 the height values on the map and on the profile do not match

GIS practice - Drawing a profile (in Lesson 8)

- When using the profile tool, the Profile Manager screen is 'sent to back' while the profile is being drawn. Should be set to stay 'on top'
- When acquiring data to draw a profile, the sun-shaded DEM is automatically selected. To visualise terrain, which is the requirement of this learning programme, the programme must default to the unshaded DEM.

.

Appendix 9.2

POTENTIAL ERROR ANALYSIS PER EXERCISE IN THE MAPTRIX GEOMATICA PROTOTYPE

Lessons	‡Exercise	Question numbers: 1	2	3	4	5	6	7	8	9	10	n*	Errors: Potential	Actual	%
		Wrong or missing answers per question													
Boundaries	H3	23	12	8	8.5	9.5	12	15	20	5	21.5	37	370	134.5	36%
	H5	4	13.5	4	17	4	10	20	24	7	19.5	39	390	123	32%
Direction	C3	6	20	7	9.5	16	17.5	15	16.5	20.5	10	37	370	138	37%
	C5	3	3	5	11	17.5	11	17	12.5	7.5	11.5	25	250	99	40%
Position	H2	9	16.5	7.5	12.5	13	10.4	7.5	13.5	12	15.5	30	300	117.4	39%
	H4	9.5	10.5	6.5	2.5	6	13	9	6	7.5	2.5	30	300	73	24%
Bearing	C2	5	4	10	9	12.5	9.5	10	12.5	16	4	30	300	92.5	31%
	C4	4.5	4	2	8	4	13	2	12	5.5	4.5	20	200	59.5	30%
Height	D3	5	4	8.5	5	8.5	10	9	14	6.5	10	28	280	80.5	29%
	D5	5	5	5	4.5	10.5	7.5	8	6.5	3.5	13	31	310	68.5	22%
Distance/ Area	D4	3	5.5	4.5	5	7	7	15	10.5	6.5	14.5	25	250	78.5	31%
	D6	4	6.5	11	4	6.5	4	10	19.5	7	11	24	240	83.5	35%
Gradient	S2	3	4	2.5	11	8.5	2.5	8	3	12	14.5	20	200	69	35%
	S4	7	4.5	4	6	5	2	4	4	6.5	15.5	18	180	58.5	33%
Profiles	S3	0.5	5	3	3	5.5	5.5	8.5	4	8	7	16	160	50	31%
	S5	0	6	0.5	4.5	2.5	8	7	6	3.5	5.5	12	120	43.5	36%
Total errors per question		91.5	124	89	121	136.5	142.9	165	184.5	134.5	180	422	4220	1369	32%

n* : number of times each exercise was attempted

‡Exercise : The exercises are numbered according to the playing cards used to identify each map extract in the MapTrix Kit: H = Hearts, C = Clubs, D = Diamonds and S = Spades

.

Appendix 9.3

MATCHING PRE- AND POST-TEST SCORES TO MAP ANALYSIS SKILLS

(Adaptation of scores for 10 map analysis pre- and post-test questions to match the eight lessons on map analysis skills in the MapTrix Geomatica prototype.)

Test question numbers (and points value)	Map analysis task	Mean pre-test scores per question	Mean post-test scores per question	Map analysis skills: lesson numbers and topics	Pre-test scores adjusted to map analysis skill	Post-test scores adjusted to map analysis skill
1 (2)	Identify boundaries	70.5 %	73.0 %	1. Boundaries	70.5 %	73.0 %
2 (3)	Name direction	52.7 %	73.7 %	2. Direction	52.7 %	73.7 %
3 (2)	Locate position from co-ordinates	38.5 %	52.0 %	3. Position	38.5 %	52.0 %
4 (3)	Measure bearing	31.3 %	44.0 %	4. Bearing	31.3 %	44.0 %
5 (2)	Give contour height	21.0 %	41.5 %	5. Height (give contour height **and** estimate height difference)	19.3 %	35.3 %
6 (4)	Estimate height difference	18.5 %	32.3 %			
7 (2)	Measure / calculate ground distance	5.0 %	21.0 %	6. Distance and area (measure **and** calculate distance and area)	20.0 %	37.0 %
8 (2)	Calculate gradient	3.0 %	12.0 %	7. Gradient	3.0 %	12.0 %
9 (4)	Calculate (rectangular) area	27.5 %	45.0 %	(Incorporated into Lesson 6)		
10 (6)	Draw and describe profiles	20.8 %	30.2 %	8. Profiles	20.8 %	30.2 %

Appendix 9.4

ADJUSTING MARKING MEMORANDUM FOR GREATER FLEXIBILITY

(Adjustments that were made to marking memorandums for S and T tests which were then used to assess the impact of numerical accuracy on the test scores of Group SV)

Test question number and task (marks /30)	Map Analysis S Test			Map Analysis T Test		
	Original accepted answer, for full marks	Original leeway for answer, half marks	Adjusted answer (for full marks unless indicated)	Original accepted answer, for full marks	Original leeway for answer, half marks	Adjusted answer (for full marks unless indicated)
Q4 Bearing (3)	12°, 13°, 14°	11°, and 15°	10 (°) to 16 (°)	83°, 84°, 85°	82° and 86°	81° to 87°
Q5 Contour height (2)	380 m	none	360 (m) to 400 (m) for half marks	120 m	None	100 (m) to 140 (m) for half marks
Q 6 Height difference (4)	435.5 m 160 m 275.5 m	none	350 to 450 (m) 140 to 180 (m) 210 to 310 (m)	1 073.5 m 360 m 713.5 m	None	1 060 to 1 080 (m) 340 to 380 (m) 700 to 720 (m)
Q7 Distance (2)	900 m	850 m to 950 m	800 to 1 000 (m)	900 m	850 m to 950 m	800 to 1 000 (m)
Q 8 Gradient (2)	1:3.3	Rounded down	1:3.2 to 1:3.8	1:1.26	Rounded up	1:1.1 to 1:1.4
Q 9 Area (4)	7.7 km 4.6 km 35.42 km²	32 to 38 km²	7 - 8 (km) 4 - 5 (km) 28 – 40 (km²) (half marks)	7.7 km 4.6 km 35.42 km²	32 to 38 km²	7 - 8 (km) 4 - 5 (km) 28 – 40 (km²) (half marks)
Q 10 (a) Draw a profile (4)	End heights must be accurate, two points for accurate shape	Small variation in shape	Approximate end heights and shape awarded full marks	End heights must be accurate, two points for accurate shape	Small variation in shape	Approximate end heights and shape awarded full marks
Q10 (b) Match profile shape with description (2)	c	none	Description instead of letter option	c	none	Description instead of letter option