LEARNING TO READ

THE SOUTH AFRICAN 1:50 000 TOPOGRAPHIC MAP:

THE DEVELOPMENT OF A SELF-INSTRUCTION METHOD

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DECLARATION

I declare that the contents of this dissertation are my own unaided work. The dissertation is submitted for the degree of Master of Education in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at any other university.

Lorraine Innes

20th day of October, 1998

DEDICATION

To David, Jo-Anne, Peter and Laura

... who so often had to wait while I kept on, keeping on ...

ABSTRACT

The place of topographic map reading in geography education is discussed with particular reference to South Africa. Theories of literacy acquisition and geographic and spatial concept development are related to the teaching of map reading. The extent of and reasons for poor pupil performance in mapwork as well as its consequences are examined. Using outcomes based learning principles the task of reading the 1:50 000 topographic map is analysed, the skills required to perform the sub-tasks of recognition, identification and comprehension are identified and a method is developed to sequence the teaching of these tasks. Programmed instruction design is investigated and self-instruction materials for reading the South African topographic map are developed. Results of a pilot test conducted when the programme was in a formative stage guided the final layout of the materials. A teaching kit comprising 52 work cards and corresponding answer cards and a pupils' answer and record booklet was used by learners in grade nine during a classroom trial and the results are reported. The use of the self-instruction method improved the map reading performance of this small sample population of adolescents. Improvements to the prototype and further testing are recommended.

Keywords: Map literacy; mapwork; cartographic communication; topographic maps; geography education; spatial concept development; graphicacy; self-instruction; outcomes based learning; teaching programme; Maptrix; .MapAware.

PREFACE AND ACKNOWLEDGEMENTS

READY ... **AIM** ... FIRE...

Having recognised a need for, and being ready to change map literacy education, a procedure was planned with a clear aim in mind. Warmed with the fire of enthusiasm, I set out to develop a self-instruction programme to improve mapwork performance. What actually happened was a series of false starts, the unearthing of many false premises and a protracted battle against time and circumstance, during which the project was often steered off course, set aside for lengthy periods and dismantled for maintenance and repairs. It was during one such course adjustment that the following words on managing change in education were most encouraging:

READY ... **FIRE** ... AIM ...
(Fullen, 1995, 31).

Looking back over the six years of registration as a part-time student and the two years before that while trying to get a proposal approved, I had often become frustrated by what appeared to be an inconsistency with accepted research procedure. Fullen's honest exposé of what really happens in attempting to make a change in education helped me see that the winding path which had been followed was normal. All I had to do was keep on keeping on. In the education system one change is seldom going to make a difference on its own. To be effective, each change must have a knock-on effect. This was reflected in the development of a microscale teaching system too. It is only once the first change has been made (the first shot fired) that one can identify areas where the next change needs to be managed. Thus Fullen advises get ready, fire, aim...

The protracted period of time, 1990 to 1998, during which this research was conducted, spanned major changes in the government of South Africa, and the impact that this has had on education policy. The outcomes based focus of the National Qualifications Framework (NQF) reflects many of the gut feelings that I had always had about teaching. I believe that the teaching method developed during this research exercise fits the pattern of solutions to the problems caused by previous shortcomings in education policy.

The changes in government are reflected in the attitude of the country's national mapping organisation (NMO), the Chief Directorate of Surveys and Mapping in the Department of Land Affairs. In the past, the majority of the country's inhabitants had limited access to spatial information, thus many adults currently have low levels of map literacy skills. Because map illiteracy is hampering the process of land reform, a national Map Awareness and Map Literacy project (MapAware) was launched in February 1998. Much if the investigation and some of the findings described in the report that follows have been incorporated into this project.

Although this dissertation is submitted with the approval of the Chief Director of Surveys and Mapping, the views and opinions expressed are those of and

do not necessarily reflect the views and opinions of the Chief Directorate: Surveys and Mapping.

Professor John Earle of the Department of Geography and Environmental Studies at the University of the Witwatersrand, Johannesburg, supervised this research. His kindness, encouragement and guidance over my protracted period of registration are acknowledged with deep gratitude. The help of co-supervisor, Professor Shirley Pendlebury of the Faculty of Education at the same university was most useful in the final stages of preparation.

Many computer fundis have come to my aid: geniuses amongst them include Asia Pacek, Sandra Turk, Angelique Merrit, Heather Mann and Aslam Parker. Donations during early stages of the project are acknowledged from Nashua for colour copying services and from the University of Bophuthatswana (now University of the North West) for a small research grant. My thanks go to Elaine Spencer-White whose photography enhanced the quality of the learning materials and to Jacques Pienaar who assisted her and later photographed the classroom trial. The enthusiastic involvement of pupils and staff at Cape Town High School in that trial was indispensable. The outstanding cooperation from staff at all levels of the Chief Directorate of Surveys and Mapping have made the completion of this research project possible. Thank you to Derek Clarke, the Chief Director, for sharing my vision and then providing the resources for me to carry out my mission. I trust that the results will be of value.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 6

LIST OF ABBREVIATIONS

ABET	Adult Basic Education and Training
CAD	computer aided design
DET	Department of Education and Training
ETQA	Education and Training Quality Assurance (bodies)
FETC	Further Education and Training Certificate
GETC	General Education and Training Certificate
MapAware	The map awareness and map literacy project of the Chief Directorate: Surveys and Mapping of the Department of Land Affairs
matric	matriculation exemption examination
NMO	National Mapping Organisation
NQF	National Qualifications Framework
NSB	National Standards Body
SAQA	South African Qualifications Authority
UTM	Universal Transverse Mercator (grid)

LIST OF APPENDICES

CHAPTER 1

THE MAPWORK MALADY IN SOUTH AFRICAN GEOGRAPHY EDUCATION: SYMPTOMS, DIAGNOSIS AND PRESCRIPTION

Poor scores for the practical paper in the South African school leavers' geography examination have been noted, discussed and reported for many years. The reasons have been investigated and recommendations made for addressing the problem of poor mapwork performance at school level. The symptoms of the mapwork malady are far more serious than poor examination scores. They indicate low levels of map literacy, poor spatial concept development and the inability of a large sector of the population to use maps as a source of information for finding their way and, more importantly, for decision making in all matters related to land use.

The term 'mapwork' is used loosely to describe the variety of tasks set for assessment in the final geography examination and includes the reading, analysis and interpretation of the South African 1:50 000 topographic map. The definition of map reading used here is the recognition and identification of map symbols and the comprehension of the geographic features that they represent.

The importance of map literacy and how it is acquired is dealt with in chapter two: *Learning to read maps.* That there is a mapwork malady in South Africa will be demonstrated in chapter three, which focuses on the place of the South African topographic map in national geography education. Although a range of treatments for the malady exists, self-instruction (described in chapter four) is the prescription recommended here. Chapters five and six deal with the design, development and assessment of a self-instruction programme for learning to read the South African 1:50 000 topographic map. In the final chapter the place of the current research in the national Map Awareness and Map Literacy Project is also briefly discussed.

1.1 SCOPE

It was initially intended that a range of mapwork skills would be taught by a self-instruction programme comprising one hundred work cards, to develop ten different skills, through four different skill levels. The starting point in a sequence of learning units had to be identified, as well as the best possible order in which to present the materials. Task analysis revealed that the order in which sub-tasks had to be completed in order to analyse spatial information (as presented on a map) was not the same order as the hierarchy of difficulty of the skills required. Readings in cognitive research stressed the importance of concept development, but there was no clear guidance on what the order of such development should be. The analysis of the mapwork tasks required by the national core syllabus for geography indicated that all other mapwork skills depended on the identification, recognition and comprehension of the symbolised information on the map.

The cause of the mapwork malady was thus diagnosed as the inability to read maps. It was decided therefore to exclude the higher order skills and to focus the research efforts on the skill of map reading only. This reduced the number of work cards by half and meant that the higher order skill levels would not be dealt with.

It is intended that, on completion of the current research, collaborative teams can be established under the auspices of the national mapping organisation (NMO), to develop teaching materials for the higher order map use skills. Initially these include locating position, describing direction, measuring bearing and distance, calculating differences in altitude and calculating gradient. The envisaged instruction programme will then go beyond guiding learners in the analysis of data gathered from maps, to the interpretation of aerial photographs and maps at a wide range of scales, including orthophoto maps.

The description in the previous paragraph of what this research exercise excludes helps focus on what this research exercise includes. It is an attempt to improve topographic map reading by the use of a self-instruction programme consisting of work cards, answer cards and a pupil booklet in which learners record their answers and their progress.

The cards are divided into four main geography topic areas: rural settlement, urban settlement, landscape and transport. The thirteen work cards in each topic area are further divided into three sub topics. The front of each work card has a map extract with a brief descriptive introduction to the area and ten questions referring to information on the map. On the back of the work card is a lesson on the sub-topic and illustrated explanations of ten different map symbols. Learners must record the answers to the questions in their booklets. Having done so, they replace the work card, select the matching answer card, check their answers and record their score on a bar graph. Information in the booklet guides learners along an individualised path through the exercises, depending on each one's performance. The pace at which they complete the programme is thus learner controlled.

Although I selected the map extracts and authored the questions, lessons and symbol explanations, a number of other people were involved in the project. The alphanumeric reference and grid was added by kind favour of a CAD computer operator and a sponsor who made photocopy services available at no cost. The pilot testing of the research project was conducted with the assistance of a small group of pupil survey officers employed at the Chief Directorate of Surveys and Mapping. A cartographic proof-reader from the same organisation checked the exercise and answer texts for accuracy and validity. Two grade nine classes and their geography teacher collaborated in the trialling of the self-instruction programme at a local secondary school.

The initial research concept came to me while teaching geography at a senior secondary school and tutoring teachers who were upgrading their teaching qualifications by distance education. During the eight years that the research was in progress, it was necessary to relocate with my family to different parts of South Africa more than once. This meant that I was removed from the senior secondary school classroom situation in which I had initially planned to develop the self-instruction method. These moves, although disruptive, broadened the scope of the research from a narrow classroom-focused intervention to a more comprehensive view of the place of map literacy in South African education.

I lectured for some time at a tertiary institution where the consequences of poorly developed map skills were a particular problem for first year geography students. This provided greater insight into the seriousness of the problem. I was later to teach in the International School of South Africa where British Ordinance Survey maps were used. This gave me the opportunity to compare our local topographic map sheets with those produced in a different style and this highlighted some possible improvements to the map itself that could assist learners in the future. The examining body for which I was preparing candidates stressed the importance of map use in practical fieldwork and also the use of map sketching to draw attention to important features of the environment. These were aspects of teaching mapwork to which I had not previously paid attention and their importance became evident. Reviewing the literature on cartographic communication explained certain conventions I had not clearly understood. The importance of starting with the local map when teaching mapwork, was often stressed (for example Ottosson, 1988).

In the last year before the completion of the research I was appointed to the post of principal geographer at South Africa's national mapping organisation (NMO), the Chief Directorate of Surveys and Mapping. My role is to co-ordinate a national Map Awareness and Map Literacy Project. In this position I, at last, had the equipment and resources available to illustrate the symbols effectively and had direct access to surveyors and cartographers to clarify the finer meanings and implications of symbols currently in use. The assistance, encouragement and support received from all levels of staff are gratefully acknowledged. Without their input this project could never have been completed.

1.2 METHODOLOGY

At the outset, experimental research was envisaged using the classic test-intervene-test approach (Cohen and Manion, 1985). The development of the intervention instrument occupied the greatest part of the research and in the final analysis the test population was too small to generalise the results obtained. It is hoped that the self-instruction programme will soon be the subject of further experimental research.

The methodology used is a mixture of applied research and action research (Cohen and Manion, 1985). Applied research emphasises the establishment of relationships and the testing of theories (Cohen and Manion, 1985). One broad hypothesis is tested here, namely that the self-instruction method can be used to improve map reading performance. It was more important at this stage of the research, however, to test the validity of a variety of assumptions about the programme and about the learners whom the programme is designed to assist.

Figure 1 Stages of action research (after Cohen and Manion, 1985)

STAGE	PROCEDURE	ACTION
1	Identify the problem	Taught geography at primary, secondary and tertiary levels and found poor mapwork performance at all levels.
2	Draft a proposal	Prepared a research proposal to design a teaching programme to improve on poor mapwork performance.
3	Literature review	Reviewed research on learning, reading, mapwork especially map reading, cartographic communication, geography education, graphicacy, self-instruction, evaluation and assessment (amongst other topics).
4	Modify or redefine the problem and set clear objectives	Initial proposal turned down by Education Faculty. Asked to investigate the problems of teaching mapwork. On completion, this proposal was rejected by the Geography Department as a duplication of effort. A third proposal was eventually accepted by both parties.
5	Select procedures	The self-instruction model of Gagné and Briggs was selected, adapted where necessary and the teaching programme developed.
6	Evaluate procedures	A pilot test was conducted and findings incorporated into the prototype.
7	Implement project	School trial of prototype was conducted and data collected.
8	*Interpretation and* evaluation	*Results confirm that the self-instruction method* can improve map reading. Recommendations are made for the further development and implementation of the programme.

Action research allows a little more flexibility to change the parameters of the instrument design. It is usually an attempt to solve a specific problem (*teaching of topographic map reading)*, in a specific setting (*pupils preparing to enter the final phase of secondary education)*, to meet specific needs (*development of skills* *required for improved geography grades).* Adults who need to learn to read these maps were also considered to be part of the target audience. Cohen and Manion (1985) outline eight stages in conducting action research. Their framework (figure 1) is used to briefly outline the stages of the research project.

A formative and a summative assessment were carried out during the development of the programme. A formative pilot test was conducted once the map selection and exercises had been completed, the purpose of which was to test the efficacy of the main components of the intervention instrument. The results of this test highlighted the need for support material as well as text refinements that were incorporated into the final prototype. Lesson texts and the illustrated symbol explanations were completed to help develop the concepts necessary to read the information from topographic maps with comprehension.

The purpose of the summative school trial was to test whether the intervention instrument led to an improvement in map reading performance. A pre-experimental approach was used in which there was no control group. Two tests of equal difficulty were designed and used by alternate pupils as pre- and post-tests. A diverse group of learners in the ninth grade wrote a pre-test, followed the programme and then wrote a post-test. The period of time over which the evaluation was done was limited and the test population was small. Nevertheless, the results produced a viable data set.

Because of the approach used, there is no way to compare the results of this self-instruction programme against the improvement which could have been attained by 'normal' teacher-centred instruction. In the case of the test population in a well resourced school with an experienced and well trained geography teacher, there is little doubt that the teacher-centred method could have achieved better results than those produced by the self-instruction programme. The programme is however intended for use in schools where there are few resources and inadequately trained teachers. This highlights the need to extend the current research programme to just such schools and funding is currently being sought to do so.

Writing up a research report places a temporal pattern on the research activities which suggest a semblance of order, an impression that one step was taken at a time, in isolation from all other steps (figure 1). This is in fact far from a true reflection of the situation. As each new step was taken, previous steps were reviewed and modified. Ways of improving procedures often became obvious as soon as they were attempted.

Having searched for and, I believe, found some guidelines for treating the present mapwork malady, it would appear that significant changes need to be made in many different parts of the education system. Change is needed in the teaching strategies currently adopted, in the training of teachers, in the compilation of mapwork teaching texts and in the assessment of performance. Change is also necessary in the accessibility of, and even in aspects of the production, of the South African 1:50 000 topographic map.

CHAPTER 2

LEARNING TO READ MAPS

2.1 LEARNING

Learning probably has as many definitions as there are researchers examining the topic. An exposition on learning theory goes way beyond the scope of this work but some relevant concepts must be briefly dealt with. The questions to be addressed in this chapter include: what is learning and how does it happen; how do people learn to read; can learning to read text be compared with learning to read maps; how can learners be helped to read maps more efficiently?

2.1.1 What is learning?

The early stimulus-response theory of learning is discussed in the chapter on self-instruction. Challenges to this theory have more relevance for my research, especially the work of Jean Piaget and colleagues at the Centre for Genetic Epistemology in Geneva. One summary of their learning research describes the work as having been 'undertaken to find the extent to which children's level of understanding sets limits on what they are able to read from the environment and, conversely, to see the extent to which encounters with selected data from the environment affect the child's level of understanding' (Duckworth, 1979, 300). Although much of the terminology used by Piaget and his colleagues has been adopted by other researchers it is often italicised in this chapter so as to acknowledge its source.

Piaget (1964) differentiated between knowledge and learning. He identified the development of *knowledge structures* as a *spontaneous process* linked to *embryogenesis* which concerns the physical development of the nervous system including the mental faculties. Learning, on the other hand, he defined as a process which is *provoked* one stage at a time by stimuli which can only be recognised as such if a *knowledge structure* exists. The stimuli are then brought into *equilibrium* within the knowledge structure by the *operation* (activity) of learning.

The research findings which have had the most far reaching consequences for education were Piaget's identification of stages of cognitive development or learning ability. These have been used to organise learning situations better suited to the learners' level of ability, and have been challenged in attempts to accelerate learning (Duckworth, 1979).

Much of the experimental work done to accelerate learning showed only marginal results and is characterised by the words *struggle* and *conflict*. It is only when the learner is aware of a dilemma in what they perceive that they are stimulated to resolve the conflict (Piaget, 1964). It is in this struggle that they move from one level of understanding to another. There is evidence that these steps can be linked to language development (Vygotski, 1962) and culture (Zeuli and Floden, 1987) rather than to age. It appears that knowledge consists of conceptual frameworks within logical structures. What makes the difference between individuals is what they do with their basic frameworks and whether they can be taught to become aware of how they develop their own *logical structures* (metacognition). Büchel (1988) proposes that by making learners aware of their own learning (cognitive) strategies, they may perform more efficiently upon reaching adolescence and adulthood.

Piaget recognised that the development of knowledge is based on the refinement and reintegration of new material into the individual's existing knowledge structures. Inhelder and Piaget (1959), working at the Geneva Centre proposed that three forms of knowledge are needed for real understanding: perception, action and the conceptual links between these two. Entwistle (1987) defines understanding as the ability to form a web of interconnections between old and new experiences and facts.

Ghaye and Robinson (1989) draw a distinction between knowledge structures and cognitive structures. They worked in geography classrooms in the United Kingdom to establish teaching practices which would lead to efficient 'deconstruction of the familiar' and its thoughtful, reflective reconstruction in order to positively influence children's 'meaning-making processes'. They encouraged teachers to present pupils with a visual framework to represent a knowledge structure of the lesson topic. This was built up through interaction during the lesson; then pupils were given the opportunity to draw their own concept maps, developing a variety of links between concepts and elaborating on areas of personal interest. The researchers then analysed these 'networks' (knowledge structures) to assess the child's ability to understand what was being taught.

By the close study of children and adolescents with cognitive dysfunctions, Feuerstein (1980) identified a range of specific mental operations and thought processes. Accepting that the mental ability of every individual is modifiable (Feuerstein 1988), he has developed a programme of instrumental enrichment to mediate learning experience. The value of this approach in a multi-cultural setting, such as the South African classroom, has been identified and courses for training teachers (as learning mediators) have been developed (Skuy ed., 1991a, 1991b, 1993).

I understand learning to mean both the increase in the volume and complexity of knowledge structures and the development of the cognitive abilities for expanding these structures.

2.1.2 How does learning happen?

Piaget (1964) identified four factors required for the development from one set of structures to another: maturation, experience, social (linguistic) transmission and *equilibration.* After extensive studies with children of different ages, Piaget proposed four stages in the development of children's thinking. He identified the thought stage associated with the first two years of life as the *sensorimotor* stage. It is characterised by the exploration of the environment with vision and touch when the young child recognises the existence of objects and themselves. Thought is purely egocentric.

The *preoperational* stage Piaget identifies from the age of two years when the child begins to communicate with language. Objects can be represented by words and, as the child advances towards four years of age, objects can be represented by drawing and in some cases by written words. Thought is still egocentric and is restricted to words. Until about the age of four, children operate, according to Piaget, in the *preconceptual* phase: they are still unlikely to use concepts.

Boardman (1983), in his research into spatial concept development, identifies children from birth to four years as being at the level of direct perception. During this time young children can differentiate between objects which are near and far and they can recall spatial images (demonstrated by playing hide and seek). Graves (1975) and later Catling (1985), studying the development of fundamental geographic concepts, also found that the nature of learning was sequential. Starting with Piaget's preconceptual stage, children begin to develop an awareness of the spatial location of objects in isolation; then later connect locations in a linear fashion.

During the latter part of the *pre-operational* phase, in the years from four to seven, Piaget postulates that children become more intuitive. Although thought processes may be dominated by immediate perceptions of one relationship at a time, they are able to develop and express simple concepts such as the representation of a class of objects by one word. In agreement with Graves (1975) and Catling (1985), Boardman (1983) identifies this as the level of topological spatial perception when children can see points in relation to each other.

By the time the child enters formal schooling at around seven years of age, Piaget suggests that they are capable of *concrete operational* thought. They are capable of thinking (operating) logically but their reasoning is still related to objects and is thus concrete. The mental operations of which they are capable include the recognition of a stimulus (such as a new fact) which is then internalised and organised into a framework or structure so that they can think things out for themselves. He found that they are capable of *conservation* and *reversibility* and can mentally rearrange in front/behind and left/right. Up to the age of about twelve years they become more and more proficient at concrete operational thought, mastering several important concepts, understanding symmetrical relationships and hierarchies of ideas and using reference systems with two or more criteria.

Boardman (1983) investigated children's spatial concept development and found that by the age of about nine they have entered the projective level. They can grasp perspective relationships and the concepts of direction and orientation. They are able to represent three-dimensional objects in two dimensions but, when asked to draw a map of a familiar environment, will often mix elevation and plan form. His studies showed that the young person's view of the world from the age of nine is no longer entirely egocentric and they begin to understand the structure of spatial distributions. These findings are supported by Catling (1985).

Piaget's research led him to believe that, by the age of about twelve years, children would reach the stage of *formal operational* thought. They can manipulate in the mind experiences or objects not immediately or physically present. Young people in the formal operational thought stage can assume a stance divorced from their own opinion, assess the implications of their actions and compare real and possible scenarios. They can consider a variety of possible relationships in a data set, analyse the relationships and judge possibilities arising from the analysis. Piaget identified three interdependent but identifiable modes of thinking, *hypothetico-deductive* thought (reasoning), *propositional* thinking (following the form of the argument despite the nature of its content) and *combinatorial* thinking (considering variables in isolation and in combination to solve problems). In later studies it was found that the age of attaining formal operational thought varies widely, with estimates ranging from eleven years to eighteen years. Piaget (1964) also accepted that some people never reach the stage of formal operational thought, even in adulthood.

In examining the development of spatial concepts, Boardman (1983) suggested that the Euclidean level, comparable in terms of thought stages with the formal operational stage, could begin as early as ten years old but that it should have been reached before the start of secondary schooling. Relationships of objects in space can be structured horizontally or vertically. The concepts of open and closed spaces can be recognised and learners can begin to master distance, scale and proportion when manipulating and reproducing spatial relationships. Catling (1985) found further that, when dealing with spatial relationships, learners of the age when they enter secondary schooling, could use abstract references.

The work of Piaget, Boardman, Catling and others was done with children from developed countries. Here the general norm is for both parents to be literate, the standard of education is high, there are books and possibly maps in the home and standards of health and hygiene usually provide a satisfactory learning environment. Studies of the Piagetian Stages in developing communities show that the order of succession from one stage to another remains constant but that the ages of children entering each successive stage differ. Piaget (1964) reported that researchers, using the same experiments he had used in Geneva, found that Iranian rural children attained the stages two years later than their urban age mates. Children in Martinique were four years behind children in Canada (although both groups attended schools established according to the French system and curriculum).

The assumption that learners have reached formal operational thought by the time they reach high school is not borne out by evidence in the majority of classrooms in South Africa (Ballantyne, 1980; Burton, 1986, 1989). Using the levels of spatial concept development described by Boardman (1986), there is evidence that not all secondary school learners have reached the projective level of spatial concept development nor its equivalent, full concrete operational thought.

To conclude this topic it is useful to go back to the factors which Piaget recognised as important in moving from one stage of development to the next and refer these factors to problems in the South African learning situation. The age of maturation needs to be examined, especially the differences which exist between rural and urban communities and between children in low and high income sectors. Direct experience of the physical environment is known to be limited for many learners especially those in impoverished rural communities (Ndlwana 1991). In third world communities, social transmission is inadequate to engender the knowledge structures required for understanding first world norms, of which map literacy is one example.

For the majority of learners in South Africa, a further problem is the fact that linguistic transmission at school is in a language other than the mother tongue (Langhan, 1993; Mackrory, 1995). The language barrier inhibits the development of concepts at secondary school when the final examinations are written in English or Afrikaans. Levels of self-regulation or *equilibration* are difficult to assess independently of the other learning factors. In many cases the problem may lie with an education system which has exposed learners to teaching situations which encourage memorisation and which has not fostered the development of more complex cognitive strategies. Rote learning has been the order of the day in most under-resourced schools where teacher training in the past depended on the same style of instruction (Walker, 1994). These problems will receive further attention in the next chapter (3.7).

2.2 LEARNING TO READ

As with the section on learning, it is beyond the needs of this work to investigate the great variety of reading theories but the most important trends which have relevance for map reading must be touched on briefly. Silberstein (1987) reviewed twenty-five years of reading instruction and Kitao (1989) dealt with the role of reading when researching second language learning. Because the language of the map can be seen as a second language to all readers, the latter work provides useful insights, while the former provides a historical framework for investigation.

During the post-war period both American and British language teaching programmes shared a focus on oral language (Silberstein, 1987). The order of language instruction was taken to be listening, speaking and, when these were established, reading and then writing. 'The process of learning to read was thought to be fairly mechanical: students developed habitual (eventually automatic) recognition of the written symbols corresponding to familiar (that is, spoken) language patterns' (Silberstein, 1987, 28). The Americans did not stress phonetic language instruction to the point of producing a phonetic reader (Tibbitt, 1955) as was the case in Britain, but the trend in the United States was towards reducing the status of reading in language instruction. It was teachers of English as a foreign language who kept up the tradition of reading and later began to influence teaching trends in the United States.

While studying memory, Bartlett (1932) developed *schema theory* to explain how the reader (or listener) uses existing background knowledge to understand and recall a text (or discourse). It was forty years later that psycholinguists studying reading comprehension revived interest in this work. Kitao's (1989) summary of schema theory is useful here; '..schemata are highly organised, generic knowledge structures composed of 'slots' or 'placeholders' for each component, including information about constraints on what can fill the slot and the relationships between slots' (Kitao, 1989, 4). Schemata are used to guide actions in unfamiliar situations and to aid learners in comprehension by making it possible to infer meaning which is not explicitly stated.

Goodman (1967) challenged the traditional mechanistic approach to reading which postulated that the reader works from the alphabetical symbols (marks on the page) up through words and sentences to meaning. He saw reading as an interactive process between the reader's predictions of meaning and the actual text. Kitao (1989) reported that the findings of Weber (1970) and Stevens and Rumelhart (1975) showed that the errors made by novice readers were the result of 'seeing' what they expected to see or what they expected would fill the next slot in their schemata.

Frank Smith (1985) suggests that comprehension is possible only once children have formed their own unique theories of the world, with which new information is matched. They learn constantly by matching a new word or situation against their existing world view. He proposes that while reading they unwittingly and unknowingly apply the scientific method to each new piece of information. They hypothesise, they test their hypothesis, they observe the results and use these to confirm or reject their hypothesis. If the hypothesis is confirmed then that is one more aspect of their world theory. If the hypothesis is proved wrong, they look for some other way to make sense of their new-found information. These mental operations correspond with Piaget's equilibration, a vital factor for development from one stage of learning to the next.

Where there is lack of prior knowledge against which to test new information, readers do not know what to expect when they test their hypothesis. If they do not know what to expect, it takes much longer to make choices about what tests to apply in order to make sense of the new situation. Once the young learner is familiar with the context of the new information, the choice of alternative hypotheses to test is reduced. In this way new information is assimilated faster once a structure of possible explanations exists. Smith's (1985) research estimated the level of prediction or guessing done in order to adapt new stimuli into the existing theory of the world when reading new words. He produced timed reactions to new information from the time of presentation to time of assimilation. Of particular interest was his finding that trying to assimilate too many visual stimuli simultaneously caused tunnel vision. This blocks the brain's ability to process the visual stimuli and slows down the process of assimilation.

Since the eighties, researchers have stressed that reading is an interactive process: if students are made conscious of their purpose for reading they can adopt an appropriate approach to make the reading more efficient. They can be taught strategies for developing comprehension based on the knowledge that skill depends on interaction between linguistic knowledge and knowledge of the world. The learner needs to know what is possible in order to predict with some degree of accuracy. According to Smith (1985) readers need two kinds of preknowledge in order to expand their concept base: knowledge of the topic and knowledge of the language of the text.

Silberstein holds that 'meaning is created through the interaction of text and reader' (1987, 31). The process of creating meaning depends on both top-down processing (from the reader's preknowledge) and bottom-up processing, from the text. Carrell (1984) has identified five causes for the breakdown of bi-directional processing in second language reading: the absence of relevant knowledge structures, inability to activate existing structures, linguistic deficiency such as the inability to recognise vocabulary, misconceptions about reading, and inappropriate cognitive styles. To address these and other breakdowns in the interactive reading model, the role of the reading teacher must change.

Grabe (1985) suggests that reading teachers should 'facilitate reading, raise consciousness, build confidence, ensure continuity and systematicity, show involvement and demand performance' (in Silberstein, 1987, 32). There is no reason why there should be a difference between this description of the reading teacher's role and the role of the geography teacher who is teaching map reading.

2.3 LEARNING TO READ MAPS

What is a map? Muehrcke (1978) defines a map as any geographical image of the environment, encompassing maps that hang on a wall, hand-held working maps and our cognitive maps. These mental maps are our impressions of what a place is like, based on our limited perceptions or inferred information. He defines map reading as translating its features into a mental image of the environment and suggests that from reading a map an appreciation of what a place is like (including position, direction and distance) can be gained. Although he emphasises the role of understanding the conventions of the cartographic process as being the best way to improve map reading ability, he also asserts that, as with understanding written text, so it is with a map: 'the more you bring to it, the more you will get out of it' (Muehrcke, 1978, 252).

Muehrcke (1978) recognises that maps are not easy to understand: part of the reason is that it is the mapped world which we are trying to understand, not the map itself. Like Smith (1985), who suggests that we learn new words by fitting them into our existing theory of the world, Muehrcke (1978) suggests that we learn about places by fitting details of a cartographic map against our cognitive map. When the two correlate (merge) we become sufficiently familiar with our environment to move through it with ease and confidence. He recognises that this is seldom the case and that most people are nervous about using maps and often refer to them when already lost and panic stricken. Muehrcke (1978) points out that relating a map to the Earth is not something that happens intuitively but is a skill that must be learned and practised. One reason that he cites for the problems of poor map performance is the simple fact that people are never taught to read maps because it is assumed that maps are easily understood.

Keats (1982) refers to a map as one of the primary means of communication along with language and mathematics. He notes that although map use is a highly complex activity it enjoys far less attention than the other means of communication in formal education. He examines the whole process of map use, starting with visual skills. The detection, discrimination and identification of map symbols he considers to be the preconditions for map use. Interpretation is the processing of information 'in order to be actively employed to deal with a particular map-using task' (Keats 1982, 13).

2.3.1 Reading the map text

I understand map reading to be the identification and recognition of map symbols (including the descriptive words and place names) and comprehension of the geographic features which they represent. Map reading is a prerequisite for all other map tasks including the drawing of maps as well as the analysis and interpretation of spatial information. Visual acuity must allow for the detection of the map symbols and the discrimination of one symbol from another (Keats, 1982) in the same way as letters of the alphabet must be seen in order to read any kind of text.

Learning theory suggests that young people learn by progressively building up their understanding of the world by testing each new piece of information against what they already know. Reading theory suggests that a knowledge of the topic of the text and of the language conventions of the text are necessary in order to comprehend the text. It appears that map reading brings both these theories together to construct spatial comprehension.

The topic of a map is generally a representation of all or part of the Earth's surface. The vocabulary of the 'text' is the map symbology. The language conventions of a map are explained through the medium of geography. Concepts such as natural resources found in the landscape, infrastructure, especially transport, urban and rural settlement all build up the topic knowledge for reading maps. The cartographer uses symbols, individually and in groups according to the conventions of cartography, to write the text. If Smith's (1985) theory of reading text can be applied to map reading then this takes place using a framework of geographic knowledge against which to test predictions.

'If you can't map it, then it's not geography', is an old adage often quoted to stress the importance of maps to geography. It appears that geography is just as important to maps; without a geographic frame of reference, maps cannot easily be read.

2.3.2 Maps as a medium of communication

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). The map reader was recognised as having a role in decoding the communicated message. It was accepted that, if the communication is to be successful, then 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. Publications appeared which purported to guide the map reader towards an improved ability to use maps. Many of these attempts simply explained the map-making process and assumed that the reader would reverse the process and understand the meaning of maps.

In the preface to his book 'written strictly for the person who wants to use maps' Muehrcke (1978) claimed that his was the 'first comprehensive, philosophical, theoretical, and practical treatment of map appreciation' (p vii). He differentiated between map reading, map analysis and map interpretation, three different skill levels which had only vaguely been distinguished from each other previously. Although acknowledging the findings of perception studies, the greater part of his publication was focused on cartographic conventions. This suggests that he adopted the traditional mechanistic approach to reading by postulating that in explaining cartographic conventions, he was supplying the reader with all the tools he would need to understand maps.

Hodgkiss reflects a different cartographic focus by stating that 'a map is a form of graphic communication designed to convey information about the environment' (1981, 4). He sees the final step in the communication process as observation, reading and interpretation by the map user to create an image of the real world. He equates cartographic language with spoken language, comprising a grammar of basic concepts such as scale and a vocabulary of conventional symbols. He recognises the cause of cartographic communication failure as the reader's insufficient understanding of the complexity of the map and cartographic techniques (rather than the user's insufficient preknowledge of the environment depicted by the map).

In his research into map design for more efficient communication, Castner (1979) pointed out that there were factors over which the map designer had no control. These included the map readers' levels of experience and the time they would be prepared to spend on the map task. He identified a hierarchy of intellectual functions beyond the passive viewing, which takes place in the first few seconds. Active perception, scrutiny, information processing and image editing successively lead to deciding what the map means.

Gerber (1984) traced the history of research into map use by children. His work reflects the development in cartographic communication of an acceptance that 'it is the map designer's ultimate responsibility to minimise the discrepancy between the message intended and the one received' (p 205). He examined the influence on children's competence in map use, of three cartographic factors (colour, generalisation and positioning of map lettering) and various map-user characteristics. His findings reflect developments in reading research which stress the importance of the cognitive structures which the users bring to the map reading task.

The trends in reading research suggest that understanding is not generated one piece at a time from symbol to meaning but rather that meaning is created from prior knowledge of the topic and the linguistics of the text operating together (Silberstein, 1987). Smith (1985) offers more insight to illustrate comprehension. He showed that, the more 'behind the eyes' knowledge the candidate has, the fewer 'in front of the eyes' clues he needs. The problem of limited background knowledge is that one cannot easily substitute visual images for lack of prior knowledge, because of the problem of tunnel vision. The physiological limitations on processing visual information have been measured. The brain takes time to read (understand) what the eyes see (look at). By bombarding the brain with more visual information, tunnel vision results, effectively blocking the comprehension process. This is a particular problem in map reading where the viewer has to create some kind of order out of an apparently chaotic visual array (Peterson, 1985). He refers to the development of visual pattern recognition as an important map use skill.

The language of maps is considered in this work as a second language to all learners. In examining the use of schemata theory to understand text in second language learning, Kitao (1989) reported that students use schemata very differently. Where it could be established that schemata were not used, the reasons were mainly that the learners did not have the necessary schemata, did not use their existing schemata or they used the wrong schemata. She did, however, report that Hudson (1982) found that advanced second language learners used relevant schemata without guidance and that learners at lower levels could be helped to activate schemata to improve comprehension rates.

Guelke (1979) is of the opinion that, to ensure that the novice map reader can attach meaning to the elements of the map, a need must be created. The need may be as simple as passing a test but, more important, the need to know or understand geographic relevance must be stimulated. He proposed that the key to assisting novice map readers to become competent is to give them a reason to need to know. 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.

In the late eighties, the role of Piagetian Theory in geography education was highlighted by Downs et al (1988) when investigating the role of cognitive development in map comprehension. They found that Piaget's work was valuable because it provided an inclusive general theory of cognitive development, spanning a wide range of ages and domains. Piaget's research had led to the development of education curricula which match ability with existing schemata and emphasise the importance of challenging learners to assimilate new structures. His work had dealt with the representation of space and the use of logic, both central to map comprehension.

Downs et al (1988) expressed the concern, however, that children did not automatically accept maps as representations of the real world. They need to grasp the *stand for* relationship on two levels. First, they need to accept on the holistic level the relationship between the referent (the real world occupying space) and the symbolic representation (the map). Second, they need to grasp the relationship on a componential level where each component of the map represents a component of the real world. Further, they found that the novice map reader must have an understanding of a concept in order to understand its representation. Once learners know what they are looking at on the map, they can 'look through the representation to the world behind it' (Downs et al, 1988, 686).

2.3.3 Assessing map reading

A variety of procedures can be used to assess map reading ability. There is the orienteering method, much favoured in military training and now a popular sport in some countries (such as Britain), in which reaching a predetermined destination within a limited time signifies a measurable level of attainment. Some assessment tasks require that a sketch map be drawn using information read from a map. Should one have to be able to draw in order to prove that one can read? This is analogous to the assumption that a learner must be able to write a story in order to demonstrate that they can read a story. Many of Piaget's tests were based on drawing; representing the perceived mental image on paper. Were these valid tests? Donaldson (1978) further queried Piaget's findings on the basis that the children had not achieved the language comprehension skills necessary to carry out his instructions.

For many years the reading of maps was tied to Piaget's thought stages (Downs et al, 1988). Although, in the drawing of maps, these stages of development may well be relevant, work by Blaut and Stea (1971), Anderson (1995) and others have shown that 'reading' the vertical image (from simple hand drawn maps and photographs) may in fact occur much earlier than Piaget suggested. If we accept Muehrcke's (1978) definition, that a map is any geographical image of the environment, then these vertical images are also a form of map. What constitutes map reading and how can it be assessed?

The methods of assessing map use in the South African geography matriculation examinations have varied from department to department and have undergone changes over time (Burton 1990). The general pattern has been to ask a limited number of comprehension-type questions, more analytical tests using mathematical calculations, and arbitrary exercises based on maps such as calculating change in magnetic bearing. The pure reading of maps in order to gain information about the environment represented is seldom required. When learners perform badly in the analytical and interpretative tasks, then the general assumption is that they cannot read maps.

In those instances where learning has taken place, reading skills have been acquired, and geography education has been available to learners, school leavers should have acquired the mental constructs to understand spatial relationships as represented on maps. They should be able to orientate themselves, recognise distributions and identify boundaries. In South Africa this is not always the case. The results of the matriculation mapwork paper in geography (the only measurement device readily available) indicate very low levels of performance when using maps (Burton, 1986; Cowie, 1994). This situation is not unique to this country. In America Downs and Liben (1991, 310) found that 'many adults have difficulty on Piagetian spatial tasks designed for children'.

Perhaps the best way to get a general impression of a nation's map reading ability is to note the number of maps on display in public places and to test the availability of high quality maps to members of the general public. Countries scoring well on these two criteria could be described as having a map culture such as the United Kingdom and the United States of America. Despite the production of high quality maps at a range of scales in South Africa, there is little evidence of a map culture. One wonders if this is a cause or a symptom of the mapwork malady?

During the three years following the first democratic elections in South Africa, which gave dispossessed people the legal right to reclaim their land, very few cases came to court. One reason for this delay is that the claims cannot be expedited any faster because in many instances neither the claimants nor the government officials charged with this task are aware of or can read the required maps. Responding to this problem, the Minister for Agriculture and Land Affairs, Mr Derek Hanekom, has launched MapAware, a national map awareness and map literacy project (address to the National Assembly, 23 April 1998).

2.4 IMPROVING MAP READING

Duckworth (1979) suggests that to teach efficiently we need to use only the child's natural striving to understand the world and then to open up parts of the world 'that they may not, on their own, have thought about thinking about' (p 311). Maps provide one means of opening up the world. Muehrcke (1978) noted that one of the main reasons that people struggle to use maps is that they were never taught to read maps because it is assumed that this is easy. Feuerstein's (1980) first principle of mediation is intentionality and reciprocity. It is only when an intentional effort is made to teach map reading and there is a reciprocal desire for this learning that map reading can be improved. Chapter three deals with the teaching of map reading in South Africa.

Ottosson (1988) reviewed research into work with children and maps and suggested two important considerations when introducing maps to children. 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. The problems arising from teaching mapwork for its own sake, rather than as a tool for studying the real world, were highlighted by Sandford (1980, 1986). When irrelevant tasks are performed in unreal contexts, maps become undervalued by learners. He encourages free and directed map search and offers guidelines for improving map reading by addressing real issues with local relevance.

Apart from improving methods of teaching map reading, methods of improving maps to make them easier to read, have also been investigated. In the quest to produce more readable maps, the link between cartography and cognitive psychology has long been recognised. Olson (1979) examined the link between the map as a visual sensory stimulus and cognitive constructs. She suggests that the eye perceives unrelated bits of information which are then processed, using different cognitive constructs, to build an understanding of the data or spatial information represented on the map. Although the order in which the map information is viewed may differ, the final mental construct which is produced leads to similar results. She suggested that different people will use different strategies to perceive the input but ultimately the comprehension will be essentially the same.

Olson (1979) further suggested that, by creating measurable outcomes of the mental processes which lead to a mental construct, the way could be found to match map making to the needs of the map reader. During the eighties, when communication theory directed research into map reading, it was proposed that the process of map reading was the reverse of map making. 'Comprehending a map probably involves processing and conceptualising whole sets of symbols before dealing with individual symbols' (Olson 1979, 38). This differs markedly from compiling a map which involves selecting from whole sets of information and deciding how best to create an image from one small piece of information at a time. If learning is the understanding of meaning, and the role of map makers is to endow the maps which they produce with meaning, then this meaning should be the first principle guiding the data selection and generalisation of information on the map. By starting with geographic meaning, there is a clear guideline for what needs to be shown.

Apart from the selection and generalisation of data are the decisions about which symbols should represent the selected data. Symbol shapes, colour (both hue and intensity), line thickness, type size and font, and other cartographic conventions have been investigated by Keats (1982). Guidelines have been produced for positioning type (Gerber 1982), improving aesthetic appeal and reducing visual 'clutter'. In this regard, eye-movement studies were conducted to assess users' responses to map complexity (Castner and Eastman 1984, 1985).

It is questionable whether symbols can be improved to make the map more readable for all users. What may seem easier for one reader or one cultural group may in fact not be easier for another. One example might be colour intensity. Strong colour may appeal to those whose culture is expressed in bold colourful decorations, while for those from a more conservative background, symbols in subtler shades of low intensity would be more appealing to the eye and thus easier to read. Clarity of the reference list or key may require more attention than the symbols themselves.

More recent research has called the early cartographic communication model into question suggesting that the concept is too simplistic. There are many levels of processing required to understand a map. Different people may well use different constructs to understand a map and therefore there can be no certainty that the end results will be comparable. Although efforts by cartographers to improve the readability of maps have had a significant impact on cartographic conventions, these alone cannot guarantee improvements in map reading.

Much of the research on map appreciation and map reading was done on the assumption that local maps were readily available to learners. This is not the case in all countries. In Spain, the Institut Cartografic de Catalunya (1997) recently 'made available to people their own territory' by publishing one sheet at a time, over a period of 41 weeks, the entire 1:50 000 provincial map series in a popular weekly newspaper. One of the objectives was to introduce a cartographic culture equivalent to the rest of Europe.

National mapping organisations (NMOs) in the United States and Britain, already referred to in 2.3.3 as having a map culture, have long since accepted the responsibility for promoting map awareness and map literacy. In the United Kingdom, educational publications and materials have been developed for both high school (Ordinance Survey, 1997a) and primary school. One example is the production of the Map Symbols Flashcards (Ordinance Survey, 1997b). Geography Through the Window (Geographical Association, 1998) is the theme of this year's Geography Action Week which is supported by the NMO because of the strong focus on using local maps to describe and explain the geography of the area around the school.

In the United States of America the focus of the NMO's involvement in map user education is on environmental issues such as natural hazards and the wise use of natural resources. The materials are provided so that 'more Americans will learn to understand the world of information on maps' (U.S. Geological Survey, undated).

The proceedings of the joint ICA Commissions/Working Group Seminar on Cognitive Map, Children and Education in Cartography (*sic*) presented evidence that in many countries interest is being shown in map literacy education. Many aspects of the relationship between maps and children were covered by researchers from Japan, the host country, China, Greece, Poland, the Czech Republic, amongst other European countries, the United States and Canada. In the session on Cartographic Education for Children, Meissner (1997) described the game-like approach of teaching materials which had been developed for German pupils. Feldmann emphasised that 'map reading should always be fun' (1997, 113) in his description of the use of maps in Swiss schools. Ormeling (1997) reviewed the research undertaken in the Netherlands to improve the teaching of map use. Wood (1997) examined the present position of cartography and anticipated the future impact of technology on the presentation and use of spatial information in the next millennium. He alluded to the kind of research that will be necessary to ensure that today's youth are equipped to produce and use spatial information in the future.

There are a number of methods of improving map reading. Producing more readable maps and making them more readily available, especially maps of the local vicinity, will increase the opportunity for map reading. Improved geography education and particularly map education will increase the novice map reader's background knowledge and thus improve the environmental concept framework needed to understand maps. A more realistic assessment of what constitutes map reading may show that this skill is perhaps better developed than is presently supposed. Creating a need to understand spatial location concepts may lead to increased map use and map reading ability.

Learning theories, reading theories and cartographic communication theories have been examined. The issues surrounding geography education and especially topographic mapwork education in South Africa will be dealt with in more detail in the next chapter.

CHAPTER 3

THE SOUTH AFRICAN TOPOGRAPHIC MAP: ITS PLACE IN NATIONAL GEOGRAPHY EDUCATION

3.1 INTRODUCTION

In this chapter topographic maps are distinguished from other types of maps and the history of topographic mapping in South Africa is traced. The role of geography education and especially mapwork instruction in the development of graphicacy will be briefly examined. The importance of map literacy, especially the need to be able to read and understand large scale local maps, was discussed in chapter two. Ways in which this skill should be developed in geography classrooms, as well as reasons that this does not always happen, will receive special attention in this chapter.

Just as there is a vast range of books on an infinite variety of topics, so is there a vast number of maps at a wide variety of scales showing unlimited types of information. This range of maps includes small scale world maps showing political divisions or physical maps showing relief and drainage. Thematic maps show information about the distribution of data, such as population or rainfall, at a scale ranging from the whole world down to a region or district. Road maps show transport routes, suburban streets and special function buildings like churches and schools as well as details such as street and suburb names. Topographic maps are drawn at a large enough scale to show the distribution of features on the Earth's surface and the phenomena related to them of both natural or human origin (Monkhouse et al, 1983).

Topographic maps provide the most accurate and comprehensive graphic record of the location of phenomena. The cultural features associated with settlement, the constructed features showing economic activity, as well as the natural features of the landscape can be examined at the 1:50 000 scale generally used for maps of this type. This representation is greatly enhanced by the indication of height above sea level (Liebenberg, 1986). While used in a variety of applications by soldiers, engineers, geologists, surveyors, agriculturists, conservationists, businessmen and others, topographic maps are indispensable to geographers. Gerber and Wilson (1984, 146) contend that 'a topographic map is one of the most difficult, complex, abstract types of map available for use by geography teachers with their students'. It is precisely because so much information is shown on a topographic map that it is such a valuable resource when studying the environment.

Once learners have acquired basic map reading skills, they can access much of the information required for understanding people–place relationships, an important aspect of geography. The increasing emphasis on environmental education encourages pupils to investigate their local environment. A 1:50 000 topographic map is an invaluable tool for this.

3.2 THE SOUTH AFRICAN 1:50 000 TOPOGRAPHIC MAP

The Chief Directorate of Surveys and Mapping of the Department of Land Affairs is presently responsible for producing the National Map Series of South Africa. Until June 1997 the name of South Africa's national mapping agency was the Chief Directorate of Surveys and Land Information. Following restructuring, two chief directorates emerged: one responsible for cadastral survey under the Chief Surveyor General and the other retaining the cartographic function under the Chief Director of Surveys and Mapping.

The maps are produced at a range of scales from the large scale 1:10 000 orthophoto map sheets to maps at smaller scales such as the 1:1 000 000 wall map covering South Africa on four adjoining sheets and the 1:2 500 000, single sheet, wall map of Southern Africa. The largest scale map providing full coverage of the country is the South African 1:50 000 topographic map on 1 916 adjoining sheets.

The topographic map is based on the Gauss Conform Projection. Standard sheets of the map are framed by regular divisions of 15 minutes of latitude by 15 minutes of longitude. At a scale of one centimetre to half a kilometre, each map extract is approximately 55,5 cm by 50,5 cm representing about 28 km by 25 km of the ground surface. Each map extract is referenced according to its co-ordinate position and, with relevant peripheral information, is printed on a sheet approximately 78 cm by 58 cm.

Because of their size, the sheets are inconvenient to work with on the average school desk. The current price for the 1:50 000 topographic map is R16 per sheet (Department of Land Affairs, 1998). The price is reviewed annually. 'They accurately depict the location of natural and man-made *(constructed)* features by means of symbols and colour, and elevation by means of spot heights and contours (20 m interval),' (Chief Directorate of Surveys and Mapping, 1997, *italics* my own).

The map periphery shows cartographic details such as the map projection, the data source and magnetic declination and change. The line scale and reference list or key appear below the map. Unlike the British Ordinance Survey maps intended for wide public use, the South African topographic map sheets do not have a grid of lines printed on the map to facilitate the location of features. The graticule dicing (or sectoring) forming the frame of each map sheet is marked off in one minute sections and, with some training in the use of co-ordinates, users are able to find and describe the location of features using latitude and longitude.

The South African Co-ordinate system used for surveying, based on the Gauss Conform Projection, is referenced according to distances from the equator (x) and distances from the alternate, odd numbered lines of longitude (y) which cover the country from 15°E to 33°E. Small black grid ticks are labelled in blue on the graticule frame and show the distances from the equator (x values) and from the nearest LO or odd line of longitude (y values) in 10 000 metre units. This accurate but highly sophisticated reference system is used by technicians and professionals in the fields of cartography, surveying and engineering and is seldom used or understood by the general map using public. Topographic map sheets produced exclusively for military purposes are over-printed with the Universal Transverse Mercator or U.T.M. grid. These sheets are not available to the public.

In keeping with the official language policy of South Africa prior to the April 1994 elections, wording on the topographic map is bilingual. A system was worked out to ensure an equitable use of the two official languages, previously English and Afrikaans, on all map sheets. With the adoption of eleven official languages by the government of national unity, the policy of language use on topographic maps may need to be revised.

3.2.1 A brief history

Norwich (1993) has traced the history of southern African maps. Ptolemy, the famous Greek geographer of the second century AD, groping his way towards a fuller knowledge of the world, extended his map of the east African coast to 15° south of the equator which he considered to be the southern limit of the world (Norwich, 1993). During the fifteenth century, maps of the southern coast of Africa were pieced together by Italian cartographers using information supplied by Portuguese explorers. One of these was Vasco da Gama, who opened the sea route from Europe to India. The value of these early publications, and many of those that followed, lies in their historic interest and great artistry.

Only once accurate measurement instruments had been developed could reliable mapping commence. The key invention was the portable chronometer developed in London by John Harrison in 1761 (Frazee, 1968). This instrument kept accurate time during long sea voyages. It was used to determine degrees of longitude by comparing local noon on the ship (judged by the sun's overhead position) with the time shown on the chronometer. The time difference in hours could be converted to degrees of longitude east or west of the position where the journey originated. In 1884 it was agreed that the origin or prime meridian (0° longitude) would be fixed at the Greenwich Observatory in London.

The history of the surveying and mapping of South Africa has been traced by Liebenberg (1973) and Thomas (1982a, 1982b, 1983, 1984). Within ten years of the turn of the century, topographic map coverage of parts of South Africa existed at a scale of 1:250 000 or 1,014 inches to 4 miles. Responsibility for this work lay with the British War Office which produced the Reconnaissance Series for the Cape of Good Hope. Coverage of South Africa at a scale of 1:18 000 was initiated but never completed and in 1936 the mapping of South Africa at 1:50 000 started.

In response to a request by the Survey Board, set up by the 1927 Land Survey Act, the Minister of Lands appointed a committee to advise the Director of Trigonometrical Survey on the mapping needs of the government (Thomas, 1982a). It was decided that the whole country was to be mapped at 1:50 000 with a fifty foot contour interval and, apart from the sheets covering very sparsely settled areas, was to be completed within fifteen years. Lack of funds, two World Wars and lack of trained staff as well as other difficulties held up the completion of the map for forty years. It was in March 1976 that the final map sheet was published to complete the 1:50 000 topographic map of South Africa.

Before the completion of the first map, metrication was introduced into South Africa in 1961. It was only from January 1970 that the metre officially superseded the foot in all trigonometric survey work (Thomas, 1984). Parts of the original map appeared in metric format from the first edition but revision of all 1 916 sheets took until 1991.

To ensure that all sheets in a map series are equally understandable to the reader, the use and appearance of symbols should be standardised. Technical instructions guide the map compilers who, selecting information from aerial photography and field notes, produce the initial map manuscript. In the early years the appearance of the symbols depended on the artistic skill of the cartographers who drew the final map sheet. In 1964 a style chart was produced illustrating standardised symbols to be used by cartographers on each new or revised sheet (Chief Directorate: Surveys and Land Information, 1964). Following 1964, sheets were in circulation that showed clear differences in symbology.

A new style chart, produced in 1973, included all the changes brought about by metrication (Chief Directorate: Surveys and Land Information, 1973). This introduced a third style to sheets of the topographic map series. Further changes to the symbols were made from time to time. There was a full review of symbology and in 1987 a new style chart, known as the Mowbray Style Chart, was adopted (Chief Directorate: Surveys and Land Information, 1987). This led to a fourth style of map sheet concurrently in use.

The reasons for and consequences of the 1987 changes are explained below. No literature has come to hand to indicate that there was any attempt by the NMO to communicate with the map using public or with the education authorities to explain these changes. Because the authorities responsible for setting the geography matriculation examinations and for teacher training were not informed prior to the adoption of the changes, they were not in a position to offer timely guidance to those trying to educate novice map readers in the face of much inconsistency and confusion.

3.2.2 The Mowbray style chart

When evaluated as a medium of communication, maps should match the needs of the reader with the abilities of the cartographer (Guelke, 1976 and 1979; Smith, 1977). The efforts of the NMO to standardise symbology on the sheets of the 1:50 000 topographic map was an attempt at such a match, but the focus was on what the cartographers could most easily deliver, rather than on what the users most required.

The two main reasons for the extensive changes to the topographic map symbology in 1987 were computerisation and cost. To facilitate the computerisation of the map production process, adaptations were made to accommodate the data capture (by the vector method) of all topographic information. Other changes were necessitated by the constraints of printing computer-generated maps. Due to the world wide trend towards automation some instruments used in manual map making, such as certain scribing tools, became difficult to obtain.

Because of the lengthy process of data gathering, compilation, preparation and printing, by the time a map is published some of the information that it contains is already out of date. More rapid, cost-effective map revision can be based on up to date aerial photography only, but then small features requiring field verification cannot be shown. Because the symbols are not shown on revised sheets, the map user may assume that the features no longer exist. This loss of information is only partly offset by the advantage of publishing updated map sheets more often.

No published discussion of the changes to the symbology of the topographic map has been traced (Innes, 1995). From the reference list of a map sheet published after 1987, the Chief Moderator for the geography matriculation examination produced a list of symbol omissions and changes, identified from earlier editions of topographic map sheets (Earle, pers. comm.). This was done to guide geography examiners in setting examination papers on the topographic map. This investigation focused on features, often used in past examination questions, which would no longer be represented on the topographic map or would be represented differently. When comparing the styles of symbols on earlier maps to those of the map published in 1987 (see reference list of map in appendix N), Earle found many differences. Only twelve symbols had remained the same, seventeen symbols had been changed either in colour, design or name, twelve symbols had been omitted and fourteen new symbols had been added.

The reference list on the 1973 style chart was compared with the one on the 1987 style chart on which 64 symbols are listed (appendix N). Using slightly different criteria, even more changes were identified. Because symbols can be changed in different ways, old symbols were considered omitted and new symbols were counted as additions. The changes include the replacement of a colour stipple with a colour screen, a dot symbol with a broken line symbol and the addition of information such as the framed numbers on the higher order routes. A total of twenty symbols had been dropped and thirty new ones added on the 1987 list. It is interesting to note that contour lines do not appear on any of the reference lists.

The words used as explanations for the symbols are loaded with meaning for the competent map reader but are often unintelligible to the novice. On the 1987 Mowbray style chart, twelve changes were made to the descriptive terms for individual symbols. Teachers have long battled to explain what an *other road* is; now they also have to contend with *other railway.* Another confusion is the change in name from *trig. beacon* to *trigonometrical station.* The symbol showing what is popularly known as a windmill is now correctly named a *windpump.* Because the reference list links the intention of the cartographer with the comprehension of the map reader, closer attention must be paid to the information it contains.

The 1995 1:50 000 topographic map index (Chief Director of Surveys and Land Information, 1995) showed that 642 of the 1 916 sheets (33,5%) had been printed according to the new specifications. By 1998, 826 sheets (43.1%) were available in the new style. As a result of improved technology, coverage of South Africa by updated sheets of the new series topographic map is progressing rapidly. It is necessary that all map users, especially geography teachers and examiners, are made aware of the implications of these new style maps and of the difficulty facing learners because of several different styles currently in use.

3.3 GEOGRAPHIC THEMES AND THE TOPOGRAPHIC MAP

Before looking at the link between the topographic map and geography education in South Africa it is necessary to describe briefly what is shown on the latest style topographic map. The description that follows is organised into four broad geographic themes: transport, landscape, urban and rural settlement.

3.3.1 Transport

Transport symbols have undergone the greatest revision. The changes to the road symbols indicate the development of the country's road network and the changes to road classification. The new symbols more accurately differentiate the communication utility of roads in the network, as well as distinguishing the authorities responsible for maintaining the road systems (D. Clarke and M. Kuus, pers. comm.).

The national routes form the main framework or infrastructure of the road network. They join the major cities, ports and international border posts of the country, and are the responsibility of the National Roads Commission. Freeway sections of the national routes are clearly distinguished. The arterial routes form links within the main framework and are largely the responsibility of the Provincial Roads Departments. Main roads link important towns to the major centres and are maintained jointly by provincial and local authorities. The latter are responsible for secondary roads linking smaller towns to the road network or directly to larger centres.

In the early years of topographic mapping, roads were differentiated by surveyors in the field as *engineered* roads (having culverts, bridges, road signs) and *other* roads (those not having evidence of engineered construction). The latter descriptive term is still used on current maps, but on the reference list, the *other road* symbol is shown with a bridge! Other roads (perhaps better understood as other access roads) link isolated rural settlements, such as farmsteads and villages, to the road network. These roads are maintained by the local authorities and in some cases by the residents.

The 1973 style chart shows eight different railway symbols, the 1987 chart shows three. Multiple track, single track, narrow gauge and service railways were previously distinguishing from each other and electrification of the different lines was also shown. Historical differences between rail provision are fast being eliminated by the electrification and doubling of lines on all major routes. On maps of the new specification, line thickness distinguishes *other* railways from the main rail network. *Other* railways include service and narrow gauge lines (which are labelled). Sidings are short sections of double line affording a halt and bypass on a single railway. As the importance of sidings has changed with the increased provision of multiple tracks, they are now distinguished from stations by the size of the white rectangle symbol only.

3.3.2 Landscape

Landscape interpretation has been improved by the new symbols showing erosion and sand which replace the old terrace symbol. The dry watercourses, so typical of interior landscapes in South Africa, now have their own symbol giving a better indication of precipitation conditions. The new symbols for cuttings and embankments enhance the depiction of local relief along transport routes. Maps of coastal areas clearly distinguish erosion and deposition shore lines. A black, angled line symbol shows coastal rocks and a smooth blue line and the symbol for sand, show beaches.

The changes to the vegetation symbols are less helpful. The symbols for trees and bush (in three degrees of density) have fallen away to be replaced by a single screened green symbol showing woodland. There is no indication of sparse or scattered bush cover, and both dense bush (as found in the Kruger National Park) and thick forest (as found in the Knysna area) are represented in the same way. A green boundary line and labelling differentiate state forest from nature reserves but the pine tree symbol no longer distinguishes plantations from indigenous woodland. Rows of trees are indicated where they form a prominent feature of the terrain.

3.3.3 Urban Settlement

Urban settlement symbols have remained largely unchanged. Prominent landmark features such as communication towers and water towers are indicated. Mining activity, often associated with urban development, is clearly shown using hachures to outline mine dumps. Urban open space or recreation areas are also shown. The grey tone, showing built-up areas, has been added to the reference list and is used where sixty percent of identifiable plots have been built on. This area symbol now replaces the dense dot coverage previously used in many rural areas and it must be noted that the built-up area symbol does not necessarily classify a settlement as urban.

3.3.4 Rural Settlement

Settlement in rural areas usually depends on some means of livelihood. Many symbols previously used to gain information about rural settlements have been removed making the evaluation of economic activity difficult. The hut symbol associated with rural traditional settlements has been replaced by a black dot. The signs associated with stock farming such as dipping tanks, kraals and anti-erosion walls have been omitted. Neither the telephone lines nor the footpaths linking outlying farms are now shown. Tracks are indicated if they can be identified from the photography as motorable. Those sections of tracks forming part of a hiking trail are labelled with the trail name.

The initial topographic mapping of South Africa took forty years (1936-1976). Metrication of the map took twenty-one years (1979-1991). In eleven years (1987-1998) 43% of the map sheets have been revised according to the new specifications. Many of these sheets show the more densely settled, eastern and southern parts of the country. Learners using topographic maps of their local areas are increasingly likely to encounter maps produced in the new style.

3.4 THE TOPOGRAPHIC MAP AND GEOGRAPHY EDUCATION

In the previous section an attempt was made to demonstrate the strong bond between what is shown on the topographic map and what is taught in geography lessons. Geography teachers should acquire for their classes up to date sheets of their local area (Boardman, 1983; Sandford, 1986). Apart from illustrating, in a practical way, a variety of geography topics and stimulating interest in their own environment, this will ensure that mapwork is more than an academic exercise in which pupils engage because 'it's in the syllabus'. The topographic map sheet, an invaluable data source, needs to be more fully utilised in the development of geographic skills and concepts.

The education policy in South Africa has adopted English as the language of instruction at the majority of high schools. (The exceptions at the moment are the Afrikaans high schools.) This means that the majority of learners who need to read topographic maps are learning in English, which is a second language for them. This has a significant impact on the teaching strategies that need to be employed. In order to understand maps, learners must use a list of map symbols with their one or two word labels (or descriptors passing for explanations) which, for many potential map readers, is a list of 'foreign' words. In developing instructional text for such learners, great care must be taken to ensure that the text itself is accessible to second language learners and also to explain carefully and clearly the full meaning of the symbols and the concepts they represent.

Multilingual societies are not unique. The Swiss NMO makes map reference lists available in the three official languages, and in English for tourists (Swiss Federal Office of Topography, undated). They have placed the symbols for three map series (1:25 000, 1:50 000 and 1:100 000) onto one reference list which is available as a small fold-out leaflet in each language. The eleven official languages in South Africa present a greater challenge, but only three or four predominate in each province. The provision of multi-lingual reference lists (as separate leaflets) may help to improve levels of map literacy.

The teaching of mapwork presents many challenges. Topographic map reading performance in the past has been less than satisfactory. Causes and consequences will be discussed in the second half of this chapter. Once concerns about the changes to the topographic map symbols have been addressed, confusion may be reduced, but it is unlikely that different symbols will change levels of performance. Suggesting that map literacy can be improved by changing the map symbols is like suggesting that literacy can be improved by changing the letters of the alphabet.

The top-down government strategies of the past were reflected in the approach to national map production in South Africa (Clarke, 1997). Maps were produced on the basis of what the NMO assumed was appropriate for the readers to know. During the sixties and seventies mapping agencies in Canada, USA and Britain recognised the reader as a partner in the cartographic communication process. Much international cartographic research at the time was reader-focused and the ability of the map to meet the needs of the reader was recognised as of equal importance to the cartographer's ability to produce the map. The South Africa NMO, the Chief Directorate of Surveys and Mapping, has taken cognisance of findings in cartographic research and has launched a national Map Awareness and Map Literacy Project to promote map use (Clarke, 1996, 1997; Innes 1997, 1998). This indicates, for the first time, a move towards a map user focus in cartographic communication in South Africa.

3.5 GRAPHICACY AND GEOGRAPHY EDUCATION IN SOUTH AFRICA

Graphicacy may be defined as the communication of spatial information that cannot be conveyed adequately by verbal or numerical means (Balchin, 1972). This implies both the ability to draw or compile and to interpret spatial information such as diagrams, plans, graphs, flow charts, photographs and maps (Boardman, 1983). In his investigations in Britain, Boardman (1983) found that the mapwork component of the geography syllabus provides excellent opportunities to develop sound graphicacy skills.

Literacy refers to the ability to read and write; numeracy is associated with the comprehension and manipulation of numbers; graphicacy is the ability to communicate and interpret spatial information (Boardman,1983). Poor mapwork performance is evidence that learners have not acquired appropriate graphicacy skills.

3.5.1 Future hopes and fears

Education in South Africa is undergoing sweeping changes, which started at the beginning of this decade and are ongoing at the time of writing. At some future date, when these changes can be seen in chronological perspective, a detailed account could be prepared. For the purpose of this report, reference will be made only to those documents that have come to hand.

A Curriculum Model for Education (South Africa, 1991) was proposed by the Department of National Education and discussion was invited. The threats and opportunities which this model posed for geography were outlined by Kriel (1993a, 1993b). Shortly afterwards a new Core Syllabus for Geography was published (South Africa, 1992) by the Department of Education and Culture. This was an attempt to engender tolerance and reduce the divisive influence of the former government's policy of Christian National Education (Wesso and Parnell, 1992). Although each of four provinces had responsibility for the examination of white candidates and three different national departments had responsibility for other race groups, the broad outlines of all curricula were the same in the case of geography.

The National Interim Core Syllabus directed the education curriculum until 1995 when investigation into alternative education systems led to the adoption of the National Qualifications Framework (NQF) bill. The bill was passed into law as the South African Qualifications Authority Act on 4 October 1995 (SAQA, undated). When in place, this framework will lay down educational outcomes for a range of core learning areas from grade one through to nine when the General Education and Training Certificate (GETC) can be awarded. The same certificate is available to adults who follow the Adult Basic Education and Training (ABET) programme (Ministry of Education, 1997).

The Further Education and Training Certificate (FETC) will be available to both adult and school based learners after three further years of study. This certificate will replace the current Matriculation Certificate providing access to tertiary education (Lötter, 1997a, 1997b). In the new system, provision is still made for twelve years of formal schooling (Ministry of Education, 1997). This new system is being phased in over a period of time that should allow the transformation of the education system to be completed by 2005 (SAQA, undated). The NQF will be implemented one year at a time, in grade one first, then in grades two and seven, then in grades three, four and eight, followed by grades five and nine, six and ten and in the last two years, grades eleven and then twelve. For the time being the guidelines of the National Interim Core Syllabus are followed for the interim grades. The two education systems will thus operate side by side for this period of time with the older syllabus falling away in some grades each year.

The implications of the change for geography education are far reaching in that geography will no longer be taught as a school subject up to grade nine as is the case at present. The skills, previously the domain of the geography teacher, will be taught by non-subject specialists in two learning areas named the Human and Social Sciences and the Natural Sciences. It is only in grades ten, eleven and twelve that geography will retain its place as a school subject. Due to the focus on outcomes-based learning, the skill of topographic map reading should be assured but new guidelines for implementation in the classroom have not yet come to hand. As will be described, even with the assured place of geography (and thus map education) written into the curriculum throughout secondary school, map literacy levels are low. It remains to be seen what the levels of map literacy will be when this assurance falls away. It is imperative, therefore, that geography teachers are given support for their classes in the last three years of formal schooling to ensure that map literacy can be improved.

3.5.2 Past frustrations

In the old core syllabus for education in South Africa it was stipulated that geography was compulsory up to grade nine (previously named standard seven). 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 591, p10).

The *Working Document for Geography* (Department of Education and Culture, undated) prepared for implementation from 1993 onwards, stressed the importance of spatial concepts which can be taught through the medium of mapwork. The section for each school year opened with the reminder that 'mapwork forms the basis of Geographic studies' (Department of Education and Culture).

Geography has been selected by an increasing number of senior certificate candidates each year. Although percentages of students choosing geography in each department of education varied, approximately one third of the total chose this elective for the period 1970 to 1985 (Ballantyne, 1987). Guidelines were suggested for ensuring that this percentage be maintained and where possible increased (Clark, 1989).

Pupil enrolment with the largest education department, the Department of Education and Training (D.E.T.) for the final school examination in 1976 was 7 529. By 1984 this had risen to 63 488 (Ballantyne, 1987). This represents an increase of 743% over eight years. Comparing the 1992 and 1993 examination statistics for the D.E.T. (which include candidates from the former self-governing territories whom this department examined) shows an increase of 19 737 geography candidates in one year (Department of Education and Training, Annual Reports 1992, 1993). This represents a steady growth in geography senior certificate candidates and consequently learners who need to be able to read the national topographic map.

Chapter one opened with the assertion that the difficulties which South African learners and teachers experience with topographic map reading and instruction have been a matter of concern for some time. Research into the problems of teaching mapwork in South Africa at primary and high school has been undertaken (Ballantyne, 1980, 1987; Burton, 1986; Langhan, 1993; Potgieter and Olën, 1993). Ballantyne (1987), Davies (1988) Cowie (1994) and Sekete (1995) have discussed both the reasons for and consequences of these difficulties. Poor performance in the geography practical examinations at matriculation level has repeatedly been reported by a number of examiners (Burton, 1990, 1992) who stressed that the higher order skills of map analysis and interpretation were weak. Performance in the mapwork component of the geography matriculation examination in South Africa is generally poor, particularly amongst black learners (Burton, 1986; Ndlwana, 1991, Cowie, 1994). This implies poor performance in allied graphicacy skills (Boardman, 1985).

Could it be that some of the problems arise because lower order map reading skills are inadequately developed and consolidated before learners are expected to progress to higher order skills?

3.6 TEACHING TOPOGRAPHIC MAPWORK

Teaching involves many components of which five will be given special attention: topic, teacher, teaching aids, learners and an outcome. Problem areas can be identified in each component. First on the list is the topic, in this case the topographic map, which has already been discussed in the first half of this chapter. Problems with the key and the lack of a reference grid have been mentioned; the more serious problem of accessing topographic map sheets will be discussed when seeking reasons for poor performance in section 3.7.

Assessing the outcome of teaching reveals that the performance of pupils is poor although the method of assessment itself may need attention. It is the poor performance of the mapwork tasks required in the matriculation exam and the serious consequences of poor map literacy that initiated this research. Both will be touched on in this section. Problems associated with the three remaining components, the teacher, teaching aids and the learners, will be reviewed in the next section.

The term 'mapwork' covers a variety of activities which can roughly be divided into three types: drawing maps, orienteering (or way finding) and reading maps (used here in the fuller sense to include analysis and interpretation). Maps are drawn with the initial purpose of being read to gain spatial information. Orienteering is impossible without first reading information from a map. Data must first be read from a map before it can be analysed or interpreted. Because map reading is the basis of all mapwork, the present research focuses on reading the South African 1:50 000 topographic map. This choice does not indicate my sole concern in teaching mapwork. All types of skills and activities using maps and aerial photographs should be thoroughly investigated but this will not be done within the scope of this research.

Primary school pupils are introduced to mapwork through a variety of simple small scale maps of the world, of South Africa and of their province. During the first two years of high school, simple topographic map exercises should form part of the geography syllabus. More advanced skills are taught in grade ten to enable pupils to measure distance, assess altitude and perform certain basic calculations such as gradient. This grounding should prepare grade eleven and twelve pupils to interpret and analyse topographic map sheets.

Map reading has been defined in chapter two as the identification and recognition of map symbols and comprehension of the geographic features that they represent. The symbols are the coded language of the map. In decoding a map the reader has many problems. First, identification and recognition often involve selecting symbols and other information using a location reference. Secondly, the reader must comprehend not only the geographic significance of the features represented but also scale, direction and bearing, contours and profiles and that the two dimensions of the map represent three dimensional reality. This formidable range of potential problem areas is compounded by limitations in many classrooms.

3.6.1 Assessing topographic mapwork

Pupils' difficulties with both survey and atlas maps have been investigated in many countries: England (Boardman, 1983; Sandford, 1989), Holland (van der Schee, 1989), Nigeria (Okpala, 1989) and Denmark (Raadam, 1989) to mention a few. The difficulties associated with teaching mapwork have been outlined by many researchers and summarised by Boardman (1985, 1986) and Burton (1989). Problems were identified in the use of topographic survey maps among secondary school pupils in Zimbabwe by Davies (1983) who attempted to discern a hierarchy of difficulty so as to plan appropriate teaching strategies. Ndlwana (1991) analysed the problems experienced by secondary school pupils in the Transkei region of South Africa when working with topographic maps and aerial photographs.

Concern has been expressed about the structure and validity of South African map work examinations (Burton, 1990, 1992). There is some debate about whether the examinations reflect the objectives of the syllabus. Learners are being taught to answer the examiner's questions rather than to use maps as a source of information about the environment. A typical example of this preoccupation with what the examiner wants is the Zap Map Video Series (Eiselen, 1991) in which reference to the examiner is made repeatedly. The focus in the examinations is often mapwork for mapwork's sake rather than map use for the sake of understanding the environment better.

Burton (1990) has shown that there is a significant disparity between the examination results for the map work and theory papers for geography. This is particularly noticeable for the students of the former Department of Education and Training who are not examined in their mother tongue. A problem of assessing second language learners' comprehension, which may have relevance to map reading, is the problem of a measurement device which requires writing skills to assess map reading skills. The low proficiency writer may appear to have limited comprehension of the map because they cannot express themselves in writing. In the same way the examination candidate may misinterpret questions or may not have the vocabulary to answer them adequately.

3.6.2 *Consequences of poor mapwork performance*

Poor mapwork performance at school is often cited as a reason for 'giving up' geography. Discouraged by their own poor performance up to grade nine, matriculation candidates will often select an alternative subject for their last three years at school. This produces fewer school leavers with the well developed graphicacy skills and responsible attitude to the environment which geography teaching aims to develop.

Because of the inclusion of a mapwork paper in the matriculation examination, it is assumed that first year geography students entering college or university are competent in the skills of reading, analysing and interpreting 1:50 000 topographic maps. Verbal communication with staff at the University of the Witwatersrand, University of Bophuthatswana (now renamed University [illegible]orth West), Hebron College of Education, and Vista University has revealed that many candidates taking geography at tertiary level cannot satisfactorily interpret maps because their map reading skills are inadequate. This problem is compounded by those who did not take geography to senior certificate level and are often not map literate or even map aware.

The degree to which this inability influences student performance and shapes course design and structure has been investigated (Cowie, 1994; Chamberlain, 1995; Sekete, 1995; McGee et al, 1995). Some first year geography courses at South African universities have been redesigned to accommodate students who enter tertiary education without the ability to read, analyse and interpret topographic maps. The adjustments vary from academic support outside the scheduled first year classes to creating modular courses with a compulsory mapwork module.

At the largest distance education institution in the country, the University of South Africa, no special arrangements are made for students who enter first year Geography courses without the prerequisite map skills (Liebenberg, 1998). In her investigation of the influence of cultural affiliation on map use Liebenberg found 'a significant difference between the way in which White students and Black and Asian students understand maps' but conceded that 'a large percentage of this variance should be ascribed to the inferior schooling system for non-Whites which officially existed up to 1994' (1998, 116).

The problem of inadequate graphicacy manifests itself in the workplace in a number of ways. Consultation with a variety of organisations has revealed that improved graphicacy skills in general, and in some cases improved mapwork skills in particular, would result in improvements in productivity.

Skills required for reading building plans are similar to those taught in map reading. Both tasks require the ability to recognise symbols used to represent reality, to relate side-view to 'top-view' documents and to use scales in measurement calculations. Perhaps the most valuable aspect of mapwork is the development of three-dimensional perception. If the conceptual development required to perform these tasks can be stimulated at school level, this may facilitate the training of builders and other artisans who need to perceive three-dimensional reality (a building) from a two-dimensional document (a plan). Other skills taught in map work, such as gradient calculation, are important in terrain analyses, which must be done by the builder in order to use the site as efficiently as possible during building operations (appendix A.1).

The reading and interpretation of topographic maps incorporates a range of individual graphicacy skills such as the location of information on a grid, following flow lines, sifting information from various series which have been superimposed, and scale calculations. These skills are all required at one time or another in the fields of system design and data interpretation. The use of imaging to communicate spatial information is increasing. The use and interpretation of three-dimensional images particularly requires the development of keen graphicacy skills (appendix A.2).

Careers in the mining industry require that students are trained to use graphs, maps, drawings and other graphic material. If learners have already acquired some level of competence in the use of spatial information at high school, they must surely be at an advantage. The development of a self-instruction system of teaching to enhance graphicacy skills would be of particular benefit to large numbers of learners for whom it is imperative that cost effective alternate teaching strategies be employed (appendix A.3).

3.6.3 The impact of poor mapwork performance on topographic map production

One consequence of low levels of map literacy impacts directly on the compilation of the topographic map itself. Staff recruited and trained for this work in the past have come, almost exclusively, from those who have enjoyed a privileged education. They brought to the map making process a cultural perspective that was not fully representative of the country's broad diversity. On some map sheets the local names of small, traditional, rural hamlets have not been included and sometimes the suburb names familiar to residents of low income, urban residential areas are not shown. The fact that there have been no cartographers from such areas working on these maps has been claimed as one reason for such oversights (Pateni, 1997). Although current employment policies will address this problem in the future, 'the workforce cannot be changed overnight from a predominantly white one because of the lack of persons from other population groups with the required knowledge, skills and experience' (Clarke, 1997, 53).

There are other reasons for place names not appearing on map sheets, which are also related to low levels of map use. Should a place name be omitted in an area where the residents are map users such an omission would be brought to the attention of the NMO and could then be corrected on future editions. This does not happen where local residents are not map literate.

The National Place Names Committee, which previously reported to the Department of Education and now falls under the authority of the Department of Arts, Culture, Science and Technology, carries the responsibility for approving the official names of places such as for post offices, railway stations and towns. They also approve the spelling of the names of topographic features. Names that do not have their approval should not appear on the topographic map. Less formal settlements such as those mentioned previously are classed as topographic features by the NMO. To ascertain the correct name of such a settlement a *Questionnaire in Connection with Place Names* is used to gather information from local teachers who (it is assumed) can discuss the origin and preferred orthography of the name (Thomas, 1954, 1962). Communication barriers may exist when the officer collecting the information does not speak the local language and when the local teacher has a limited understanding of cartographic conventions and toponymy. Where the preferred local name and a name imposed by the previous administration differ, consensus may not easily be reached. In rare cases where consensus cannot be reached, a name may be omitted.

It is hoped that the present employment policy of the Department of Land Affairs, and consequently the NMO, will provide trained field staff and cartographers from all sectors of the population in the future. They would be able to verify place names in the local language of the inhabitants and also explain their significance in map production.

Maps are historical documents and, once printed (with or without errors and omissions), often remain in circulation for a long time. Inexperienced map users may interpret 'missing' settlements or settlement names as deliberate omissions when in fact the map may have been printed long before a settlement was established. Misconceptions about maps and the impact that these have had on map literacy education are referred to in section 3.7.2.

The ability to read a topographic map is a prerequisite for analysis and interpretation. Improved mapwork skills ensure improved grades in geography at matriculation level. 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. The reading of road maps is a basic life skill. The acquisition of map interpretation skills facilitates the understanding of other spatial data such as graphs, flow-charts, plans and photographs. Graphicacy complements literacy and numeracy at many levels of endeavour. Efforts to raise levels of map literacy will thus have a positive impact on general education levels.

3.7 SEEKING REASONS FOR POOR PERFORMANCE

Many reasons for poor mapwork performance have been proposed. Deficiencies in the syllabus, textbooks, teaching and examinations are probably the most serious (Ballantyne, 1987). The investigation of these reasons for poor performance helps to account for the present situation and lays the foundation for developing solutions (Ballantyne, 1982; Burton, 1989).

There are clear indications that performance is generally poor amongst the majority of learners and that the consequences of this poor performance are serious. I did not investigate the performance of learners at private or traditionally advantaged schools. The fact that many young adults are obtaining tertiary education with comparative ease suggests that, where the means and the will exist to counter the problems which will be discussed below, learners experience fewer difficulties.

The problem of poor map literacy is more pronounced in informal urban settlements and in rural areas. Many low income rural dwellers are not aware of the existence of the national map series and there are seldom street maps of such areas available. In many cases there are no street addresses because streets in informal settlements are not named. In areas where there is no postal or other delivery service nor refuse removal, there is no perceived need for a street address.

The Chief Directorate of Surveys and Mapping published an offer to supply free local maps to schools in a Sunday newspaper (Learning Press, 1997). Teachers were asked to respond giving information about the number of geography pupils and classes and the street address of the school. Over a two month period more than 100 schools responded to the offer of which fewer than half gave a street address. This suggests a low level of need for local spatial information. Guelke (1979) suggested that map reading performance could be improved by creating 'a need to know'. If there is no need for local spatial information, it is difficult to stimulate an interest in knowing how such information may be represented on a map.

3.7.1 Accessing topographic map sheets

The teaching of map reading presupposes the availability of maps, yet, in discussion with geography teachers employed in the Department of Education and Training, it emerged that original full colour maps for teaching purposes were not readily available. Photocopied map extracts are sometimes substituted and confusion results as pupils are unable to distinguish one symbol from another. Karodia and Dhoodat (undated) note in the preface to their mapwork guide that teachers who are 'often faced with shortages of maps and an overburdening theoretical component, relegated map skills to an inferior position within their scheduled teaching priority'. In some schools there are no maps at all while others have a supply of old examination maps, but very few schools have local topographic map sheets available for learners.

Topographic map extracts with an alphanumeric grid are provided for matriculation examination purposes. These should be kept by schools as learning aids and for the purpose of revision and school-based examination in the higher standards. However, this is not always the case (Pagel, pers. comm.). In the past candidates demanded the maps when leaving the exam venues claiming that they had a right to the materials as they had paid their fees. In areas where schools have limited secure storage space, the maps are collected after the exams and kept at the nearest circuit office. They may be retrieved if required, but are not readily available in the classroom to illustrate geographic concepts as they arise. School principals are reluctant to use limited school funds to order map stocks which occupy scarce cupboard space when not in use (Ndlwana, 1991).

Although topographic map reading was introduced as a requirement of the geography matriculation examination in the early seventies (Davies 1988), local maps were not readily made available to schools as a teaching resource. The NMO for many years offered schools, free of charge, outdated maps of whatever area was available for map work practice. These had to be collected from one of the few existing points of sale. During the period 1980 to 1998, the price of map sheets to the public has slowly risen from R1.14 to R16.00, an increase of almost 1 600%. Where this price is seen as prohibitive, no new maps are purchased. If available, existing stocks (often of outdated sheets) are used for internal examination purposes and are rarely used in the classroom for teaching.

In order to access a map sheet, teachers or any other users have to be able to find the correct reference code (which will be one of 1 916 codes) for the sheet covering the required area. If they can get to a point of sale they will be assisted. When obtaining map sheets by post, users must first order a map index, work out the reference number, send payment with the order and then accept what arrives without the opportunity to check whether the sheet number is correct. Due to the small scale of the reference map, it is not a simple matter to identify the exact sheet especially if the place in question is near the edge of the map sheet. Acquiring a topographic map sheet is no easy task; for a first time user it is almost impossible.

At present topographic map sheets are available from a very limited number of outlets. Topographic map sheets for the whole country can be purchased (subject to stock levels) from the Cape Town offices of the Chief Directorate of Surveys and Mapping and from the Government Printer in Pretoria. The Surveyor-General's offices in Bloemfontein and Pietermaritzburg keep the sheets of their surrounding areas in stock. Other than these four points of sale, there are only five companies throughout the country (at the time of writing) that are recognised vendors, only some of which have more than one or two outlets.

To cite the NMO's free map offer again (Learning Press, 1997), instructions for finding the reference number of the local topographic map sheet were included in the teaching material accompanying the free offer. To ensure that the free maps were despatched to bone fide cases, the senior geography teacher was asked to sign the request form. Only a very small proportion of replies carried the local sheet reference number. This was quite distressing as it was assumed that senior geography teachers would be able to use the topographic map indexing system.

3.7.2 Teachers' mapwork difficulties

The difficulties associated with teaching mapwork in South Africa have been outlined by many researchers including Cowley (1984, 1987), Seethal (1983), Ndlwana (1991) and Sekete (1995). From the above research, personal experience and discussion with many teachers employed in the Department of Education and Training, it is evident that teaching problems stem from a number of factors. Reasons for the severely limited availability of maps in the majority of schools are varied and can be found in financial constraints, lack of information and the politics of the past.

A negative attitude towards maps may have contributed to their absence from many classrooms. Their high cost and the inability to access maps using the correct code have been dealt with. Propaganda was spread for many years that it was the policy of the previous government's mapping agency not to show non-white residential areas on the topographic map because their presence was considered temporary. Although untrue, this misconception was supported by the fact that the forced removal of communities was taking place faster than the mapping of resettled areas could be undertaken. Teachers, perhaps justifiably, were opposed to teaching their pupils how to read a map that (as they thought) did not even acknowledge their existence.

Inadequate teacher training has led to a negative attitude towards mapwork because of its perceived difficulty (Davies, 1988; Cowie, 1994). An investigation of high school geography teachers' qualifications in the former homeland of Bophuthatswana revealed that 'less than a third of the respondents had an academic qualification in geography. The most common qualification of a geography teacher in the sample was matriculation with a primary teacher's certificate' (Cowley, 1987, 82). The investigation also showed that 'few teachers with a geography qualification of any sort taught the lower standards' (Cowley, 1987, 82) which is where the geographic concept base should be established.

Although this investigation was done a decade ago, the continued poor matriculation examination results suggest that little has changed.

Burton (1986 and 1989) has investigated problems with relief mapwork in South African schools. He has suggested a very practical approach to teaching contour mapping, using models to introduce pupils to the concept of relief and doing extensive fieldwork using relief maps. Boardman (1983) strongly recommends this approach. Personal communication with teachers in the Department of Education and Training revealed that lack of resources and limited teaching skills hamper the use of this approach in overcrowded, poorly equipped schools. Allied to map use, atlas use was investigated in South African schools and it was reported that teachers found their training in atlas use inadequate (Vlok, 1992).

The present problem of poor performance is likely to be compounded in the future as the number of students completing their schooling increases. As this trend continues so the pressure on education facilities increases. All improvements in teaching strategies that could relieve this pressure should be investigated.

3.7.3 Map reading instruction texts and teaching aids

The separate practical paper was introduced into the geography examination for the senior certificate in 1975 (Ballantyne, 1987). By this time, Nicholson and Morton had already produced *Working with Maps* (first ed. 1967). An exercise manual for map and air photo interpretation (Liebenberg et al., 1976) appeared a year later. These widely used publications, have been joined by others concentrating on map work entirely (Modungwa, circa 1987, Karodia and Dhoodat, circa 1996) or strongly emphasising the role of mapwork in the senior geography syllabuses (Liebenberg, 1986; Reynhardt and Holmes, 1988; Reynhardt, Holmes and Steyn, 1988). Blackbeard (1992) and Burton and Pitt (1993) have more recently made valuable contributions to the mapwork instruction texts available to South African school based learners. Scott and Collings's (1992) workbook for developing graphicacy through the use of maps, graphs and numbers is designed for tertiary level learners.

Two South African resources have been produced by the READ organisation to assist in the teaching of mapwork. The *Map Skills Chart*, is a series of flip charts and lesson plans, recently revised, for use in primary schools to develop spatial concepts (Potgieter and Olën, 1993). *Looking at Maps* (Collet, circa 1988) is part of a teaching package consisting of books, jigsaw puzzles, wall maps, a poster and an inflatable globe for use in the lower secondary school geography classes. The package is designed for use by pupils over a two month period as a self-study programme with minimal assistance from the teacher. The aim is to improve their general map reading ability. Topographic maps are not included.

Books produced outside South Africa to assist learners with map reading, interpretation and analysis were examined with a view to assessing their most useful attributes. Some books deal with topographic mapwork under general geographic techniques (e.g. Ajaegbu and Faniran, 1977) while others prescribe practice for using all types of maps (e.g. Birch, 1964; Harris and Giffard, 1970). A number of publications concentrate on topographic maps of specific countries such as Great Britain (e.g. Fullager and Virgo, 1984; Galbraith, 1979; Kemp, 1983 and Turk, 1980 and 1983); or other southern African countries (e.g. Bowen, 1982; Pritchard, 1980 and 1983). Some books teach skills that can be used for interpretation of the topographic maps of any country (e.g. Keats, 1982; May, 1991; Meux, 1975; Robertson, 1980; Ross, 1988).

It is important to establish the most efficient order in which to teach map reading skills. Textbooks largely dictate what is taught in South African classrooms. Once purchased, they tend to remain in use at under-resourced schools for extended periods, long after new approaches and techniques have been introduced. The order in which chapters are presented is usually followed slavishly by teachers especially when their own training in the subject is inadequate (Cowley, 1987). Unfortunately the tasks which need to be completed in order to build up the skills required for map reading are at odds with the order of the chapter headings of most text books.

From examining a variety of geography text books, (such as Barnard and Nel, 1982; Earle, 1985; Hurry, circa 1986; Swanevelder et al., 1987) as well as texts designed specifically to teach mapwork, (Baynes and Wheeler, 1987; Lambert, 1986;

Nicholson and Morton, 1974; Sauvain 1973), it is clear that the order of instruction traditionally follows the process of map compilation. Some start with aerial photographic techniques (Earle, 1985) others with technicalities such as projection (Barnard and Nel, 1982). It is my contention that map reading should start with a firm geography concept base, built up by carefully explaining the geographic features as represented by map symbols and explained by the reference key. Identification of symbols often appears as the fifth or sixth item in the textbook's table of contents. Nicholson and Morton (1967) in *Working with Maps* include a conventional signs list on the last page of their publication with no explanatory note. Although not at the start of the book, Liebenberg (1986) effectively illustrates geographic features represented by a wide variety of symbols.

Gardner (1986) examined the difference between the acquisition of literacy by children and adults. He refers to understanding symbols as mastering notational systems; one of which is a map. When teaching adults, their metacognitive mode enables them to appreciate explanations of the detail or purpose of tasks, for example, the use of map projections and aerial photography to capture mapped information. Children learn notation in a more direct, practical way. They may recognise the need to show information on paper (a map) but are less likely to understand how or why it should be shown. The different learning styles of adults and children may explain why authors attempting to teach map reading to children do not always start at the most appropriate place.

The skill sequence proposed by Teck (1989) emphasises that direction, location and scale should be taught before symbols but there is no way to assess how he tested the first three map skills without referring to the symbolised features on the map. Burton's (1992) research into the evaluation of mapwork in the geography matriculation examinations led to a proposed classification of map skills into four grades of difficulty according to Bloom's *Taxonomy of Educational Objectives* (1956). Burton identifies the easiest task as conventional sign interpretation. It is my opinion that this 'easiest task' should be the starting point in addressing the problems of poor performance. Boardman (1983) has graded 100 graphicacy skills according to the average age at which students should be able to acquire them and places symbol interpretation early on the list.

Instructional sequence analysis, as applied in computer based training (Gagné and Briggs, 1974; Alexander and Blanchard 1985), can be used to analyse the task of reading topographic maps. By comparing the results with present sequencing options, insight has been gained into the order in which map reading skills can most efficiently be taught. Reference will be made to skill sequencing in the next chapter dealing with instructional design.

Many of the school texts referred to above treat mapwork as a topic isolated from the rest of the geography syllabus. Although some writers caution that mapwork must be integrated into the content of the geography syllabus, little guidance is given for doing so. Research reviewed in chapter two suggests that it is their framework of well developed geographic concepts which enables map readers to read maps. Using maps as a data source in reality-related investigations, shifts the emphasis from learning what was on the map, to learning to use the map, to learn about the world that it represents, to read 'below the lines'.

The subject advisors in all education departments offer their teachers guidance in the teaching of their subjects. Workshops are held from time to time and guides are produced and distributed to teachers. A full review of these activities has not been conducted but one such guide which has recently come to hand describes a model for topographic map reading, interpretation and analysis which emphasises the importance of problem-solving and enquiry-based learning (Smit, 1994; Western Cape Education Department, 1996). After so many years of good intentions expressed in the relevant documents, this valuable guide shows teachers, in a practical way, how mapwork can 'be integrated into every section of the syllabus'.

Provision of support material may help to change the negative attitude of teachers towards maps and mapwork. In order to teach a skill such as map reading, minimal instruction is required with maximum opportunity for repeated practice. A wide variety of short, interesting map exercises to suit all skill levels is proposed. Providing immediate feedback for pupils working at different skill levels is recommended but is seldom possible in a 'normal' teaching environment. The provision of a graded set of exercises (designed so that only one answer is feasible), and accompanying answer cards will be a valuable aid to teachers working in large classes with limited resources and who are often less than confident of their own skills.

3.7.4 Learners' difficulties with mapwork

It was established in the last chapter that a framework of geographic concepts was necessary in order to read and understand maps. Many learners have difficulty with maps because their concept framework is inadequately developed. Investigating poor performance in geography at primary school level, where most children were receiving instruction in their mother tongue, Mackrory (1995) highlighted the importance of language. In order to improve concept development she recommended that a clearly defined strategy for language development should include verbalisation of geographic terms through discussion. If the young learners do not build a firm base of geographic concepts to bring to the map reading task at high school, it is unlikely that they will perform well. The world view of learners from low income areas is often limited to their immediate environment because travel far from home is seldom possible. The lack of opportunity to learn through direct and varied experience further restricts their concept development.

Despite the provision for geography education, it has been found that young learners have great difficulty with geography. One reason for this has been investigated by Langhan (1993) who suggests that problems experienced by teachers and learners 'are largely attributable to inappropriate prescribed textbooks that are difficult to read and comprehend' (Langhan, 1993, ii). He worked with learners whose mother tongue was not English. He expresses serious reservations about the change over from mother tongue instruction to English in the fifth year of schooling and shows that the texts do not take sufficient cognisance of the specific problems of non-mother tongue instruction.

For a large number of our novice map readers there are more problems than just the map language as a second language. They have the added disadvantage that the descriptive terms on the map are in a language not their own and the legend descriptors are not available in their own language either.

The coded language of the map is the first barrier that has to be overcome by a map reader. The visual functions employed in map reading have been investigated by Keats (1982). Due to the size of the conventional symbols, any vision impairment makes this barrier almost impenetrable. Dumbutshena (1993) reported that seventy percent of the pupils at the RAU College for Advancement of Learning and Leadership in Soweto, had poor eyesight. Malnutrition was cited as the cause in many cases.

Correct colour perception is vital in differentiating map symbols (Keats, 1982). An investigation of the 'colour discriminative ability of Bantu (*sic*) students' (Motshekga, ~69) highlighted the problems of learning in a second language and the effect this has on memorisation of colours, as well as the significance of culture in colour appreciation. In some African languages, the word for green and blue is the same (Sekete, 1995). Some means must be found to help learners distinguish vegetation symbols (green) from water symbols (blue). Red and black make a clearer visual impact than most other colours, often masking less obvious line symbols (Keats, 1982). How we feel about something influences the way we see it (Warwick, 1987), implying that pupils may see only the colours that they like.

Perception of map symbols and their relationship to reality have been widely studied and the results have relevance for the current research (Kirman and Goldberg, 1992; Peuquet, 1988; Warwick, 1987; Keats, 1982). Recognition of the map symbol does not imply comprehension of its meaning in reality because 'it is likely that a considerable degree of variation will occur between one individual's cognitive representation and the next' (Roberts, 1978, 19). Downs, Liben and Daggs (1988 and 1990), investigating cognitive developmental theory in relation to geographic education, focus on mapwork tasks because they are important in the development of both logical and spatial skills in children.

When teaching skills it is unreasonable to expect all learners to progress at the same pace. Because abilities differ, they must each be able to progress at their own pace. When the acquisition of higher order skills depends on proficiency at lower levels, it is necessary to ensure that every learner has the opportunity to maximise their learning opportunities. Those requiring more practice should not be hurried by the fast learners who, in turn, benefit by the opportunity to tackle more challenging tasks without being hampered by the less able learners. Differing rates of skill acquisition is a particular problem in teaching mapwork. When teachers have very large class groups, sometimes as many as fifty pupils, the majority never acquire the basic skills.

Much of the research consulted on mapwork difficulties focused on comprehension of relief as represented by contour lines. Recent research into three-dimensional visualisation in chemistry may have relevance for landscape visualisation (Tuckey, 1989; Tuckey and Selvaratnum, 1993). The identification of 'depth cues' in chemistry models could perhaps be related to 'height cues' on topographic maps. Research into other problems encountered in map reading has been reported by Boardman (1983) including the work of Salt on direction and scale and Charlton on the four basic concepts in map understanding; symbolism, scale, direction and location. Their findings indicated that pupils' abilities improved with age, in all aspects, supporting the contention of Piaget and Inhelder (1956) that understanding of proportion depends on the attainment of formal operational thinking.

Teaching mapwork must go hand in hand with spatial education (Verhetsel, 1989). Ballantyne's (1980) primary school research closely examines the problem of spatial concept development and relief interpretation. He drew heavily on guidelines identified by Piaget in extensive perception research and found that when map tasks are introduced too early, negative attitudes to the tasks are established. When trying to force learners to perform mapwork tasks before they have developed the appropriate cognitive frameworks and strategies to perform these tasks, their mapwork performance is poor. This leads to frustration and consequently demotivation.

There is a wide variety of problems that need to be addressed when teaching the reading of topographic maps which, when compared to other maps, 'are more difficult to understand because of the complex array of features which they contain' (Boardman, 1983). It is beyond the scope of this project to investigate solutions for all the problems associated with mapwork but it will attend to the problem of acquiring the foundation skill of map reading. If it can be shown that a self-instruction method developed for map reading can improve performance, then this method could be used to improve the higher level skills of map analysis and interpretation.

3.8 CONCLUSION

Five components of the teaching situation have been reviewed topic, teacher, text, learner and outcome. Problems associated with each component have been identified. It is my opinion that three steps must be taken to initiate a solution to the problem of poor mapwork performance. Firstly, local map sheets must be readily available to learners so that they can relate their local environment to its spatial representation. Secondly, the geographic concept base of learners must be broadened so that they can endow with meaning that which they read from the map. Thirdly, they must have the opportunity for practising the skill of map reading, in reality orientated exercises, so as to improve the speed and accuracy of their map comprehension.

The MapAwareness and Map Literacy Project of the NMO has already taken steps to make local topographic map sheets more readily available to secondary schools teaching geography to matric. Following the success of the free map offer (Learning Press, 1997) it has been extended until the end of 1998. MapPacks have been distributed to more than 600 schools (at the time of writing) with the intention that, having the local map on the classroom wall 'will contribute to pupils' understanding of their spatial environment' (Clarke, 1998, 5).

In the next chapter, self-instruction methods will be reviewed and the potential of an appropriate self-instruction method for improving map reading skills will be investigated. The design and early production stage of a programme for learning to read the South African Topographic Map, based on this method, will then be described.

CHAPTER 4

DESIGNING A SELF-INSTRUCTION PROGRAMME FOR MAP READING

There is probably no better way to improve a learner's performance than by using suitable illustrative materials in a one-to-one mediation between an expert and a novice. As outlined in the previous chapter, mapwork lessons in many South African classrooms are often a one-to-forty (or more) confrontation between an unskilled map reader and too many novices with insufficient maps. In these situations there is little hope of improving learner performance significantly. Although it cannot replace the one-to-one mediation of the ideal situation, self-instruction is investigated as one means of teaching mapwork which can improve performance.

In this chapter the history of self-instruction is traced. Principles for designing self-instruction programmes are identified which accommodate both internal and external factors controlling learning outcomes. A twelve step guide to the design and development of an instruction programme (appendix D) is discussed with specific reference to its use for map reading instruction. The first three of the design steps conclude this chapter. The initial development of the programme, its pilot testing and formative evaluation will be dealt with in the next chapter.

4.1 SELF-INSTRUCTION: A BRIEF HISTORY

The beginnings of a science and technology of instruction have been traced from 1900 to the late sixties by Saettler (1968). He outlines the work of Thorndike (1913), claimed as the producer of the first scientific learning theory, who formulated the 'laws' of repetition, effect (pleasure and pain) and readiness. Those who followed his approach were referred to as connectionists. They saw the teacher's role as bringing together that which should go together (the learner and the to-be-learned): when positive connections were made the learner should be rewarded; when undesirable connections were made, the learner should experience discomfort.

Dewey (1896) and Kilpatrick (1914) proposed and promoted the concept that thinking, which they equated with learning, should be developed through the reflective, problem-solving method. Studying children's behaviour at about the same time, Montessori (1912) developed a number of new techniques of instruction. Three characteristics of her approach were that schoolwork had to be adapted to the ability of the learner, that there should be freedom from teacher domination or learner dependence, and that sensory discrimination should be developed. Her approach was much criticised because she disputed the concept of fixed intelligence that was popular at the time.

In America the emphasis on individual learners' needs led to the development of materials and devices to help learners follow instructions for learning on their own (Saettler, 1968). For a time, emphasis fell on the technology of instruction or development of devices for their own sake. This contributed little to educational psychology and called the self-instruction movement into question. During this time Skinner was heralded as the father of the programmed instruction movement. He focused attention on the process of instruction as comprising a stimulus and response and then he added another stimulus (Skinner, 1953). Initially he stressed the importance of a negative second stimulus guiding the learner away from inappropriate behaviour. He later acknowledged that a positive second stimulus would be more effective in encouraging the learner towards the desired behavioural response. His work was later much criticised (Beard, 1976).

Saettler summarises the contributions to individualised instruction made by Burk (in Saettler, 1968, 63) who produced the first self-instruction bulletins; Washburne, (Washburne and Sidney, 1963) who produced workbooks providing for self-instruction and self-correction and Parkhurst (1922), who guided learners by producing individualised self-instruction assignment contracts which had to be fulfilled before a new assignment contract was issued. These researchers focused attention on home-based learners.

Morrison (1931) produced self-instruction materials for classroom use which were popular between 1925 and 1935 in Chicago. Lesson units could be selected by learners following the formula of pre-test, teach, test results, adapt procedure, teach and test again until mastery was attained. There are elements of this formula that can be recognised in the work of Feuerstein (1980), teaching in Israel many years later, using the instrumental enrichment approach. Feuerstein's work contrasts strongly with self-instruction because it focuses on the role of a mediator who, accepting the cognitive modifiability of each learner, works closely with them to realise their full learning potential (Skuy et. al. 1991a). The use of a mediating persona, to incorporate some of the valuable elements of his approach into a self-instruction programme, is discussed later in chapter five.

Lewin (1951), working in Berlin in the late twenties, incorporated some of the ideas of the gestalt school of psychology which stressed that learners respond as whole organisms to a situation, not as mechanical beings through specific reflexes. His cognitive-field theory of learning stressed the importance of assessing the learner's cognitive state before instruction so as to design the instruction most effectively. He perceived learning as problem solving which should result in changes in knowledge, motivation, ideology and possibly dexterity.

Saettler (1968) outlines the conflict between the stimulus-response-stimulus approach of those who followed Skinner and the cognitive-field approach of Lewin and later Thelen (1963). It was recognised that the systems approach, developed by the military in the United States, was applicable across a wide range of disciplines. Technology alone could not solve education problems: 'machines are not necessarily part of an instructional system (but, their use) implies a scientific study of the kind of instruction required by each learner, the time when it is needed, and the appropriate design, organisation, and operation of a system which can achieve behavioural goals' (Seattler, 1968, 271).

4.1.1 Systems of instruction and education systems

The systems approach in educational theory foreshadowed the same paradigm shift in geography and many other fields of study (White et al. 1984). The systems approach is the preferred structure for teaching many geography concepts (Haggett, 1983). A topographic map, at a sufficiently large scale, puts the local environmental system before the learner in a unique way. It is appropriate that the concept of the system is used to develop an instruction programme required to teach map reading.

As mentioned in the last chapter, South Africa is embarking on a totally new system of education. In the past a norm-referenced system was used which 'by definition (it) is concerned with comparing one individual with another' (Burke and Jessup, 1990, 195). Moving away from norm-referenced education standards, outcomes-based education has moved onto centre stage requiring a new focus altogether (Ministry of Education, 1997). Educational planners, text book writers and publishers, teachers and teacher trainers, pupils and their parents have all been exposed to and are attempting to deal with this new system. As with all change, there are those who complain that things are changing too fast, and those who complain that they are moving too slowly; change is always 'complex, recursive and messy' (Walker, 1994, 69).

Wolf (1995) traces the origins of outcomes-based learning systems to developments in America in the 1960s and 1970s. Outcomes-based training programmes were developed to reform teacher education where specific competencies were required for accreditation before student teachers were allowed into the classrooms. She then goes on to describe the competence-based versus criterion-referenced debate, distinguishing between them as follows: criterion-referenced assessment is usually linked to a formal school curriculum, while competence-based assessment is associated with vocational training where the competency is assessed in a work environment and therefore is often less academic (Wolf 1995). Her description of how these two assessment systems were adopted by British and later Australian educators and the significant impact they have had on education in these and many other countries provides interesting insights for the potential of outcomes-based map education in South Africa.

Wolf (1995) discusses the work of Fletcher (1991) who distinguishes between task analysis (the activities undertaken at work) and function analysis (the purpose of these activities). Function analysis makes possible the identification of key outcomes which can then be described according to performance criteria. Because it investigates purpose, this approach raises the question 'why teach mapwork?' The understanding that I had as a novice teacher, working with grade ten geography pupils, was that mapwork is taught so that learners can perform a series of tasks which lead to the calculation of gradient. Because I did not see the task of calculating gradient against the bigger picture of map analysis and interpretation, carried out to gain a better understanding of the environment which the map represents, I should perhaps have been asking 'why bother to teach mapwork?'

Academic knowledge is knowing *that* something is so and *why* it is so, while work skills mean knowing *how* to make it so (Dixon, 1993b). Outcomes-based learning systems should make it possible for learners to emerge from compulsory education in South Africa with both knowledge and skills as long as the learning programmes are geared to meet both ends. He goes on to stress that the only way to gain skills is by diligent practice in conditions that are increasingly real (Dixon 1993a). This approach echoes that of Guelke (1979) who proposed, more than a decade earlier, that to improve mapwork performance, novices must be put into the roles of different map-users (see section 2.3.2).

4.1.2 Further reading on personalised instruction

The personalised system of instruction developed by Keller was based on his theory of learning reinforcement (1968, 1969, 1974). Although there was opposition to some aspects of his work (Daly, 1979), his principle of positive reinforcement is incorporated into the design of this learning system. Guidelines developed to assist self-directed learners (Knowles, 1975) are considered valuable. Research in the development of self-instruction courses (Rowntree, 1979; Romiszowski and Atherton, 1979) provided valuable reading but offered no significant variations on the work of Gagné and Briggs (1974) whose model was selected for the design of the programme.

The activity theory of learning investigated by Talyzina, (1984) and Pratton and Hales (1986) reinforced my own belief in the importance of focusing the learner's attention through goal-directed action as opposed to the sit and listen approach often adopted when resources are limited in the classroom. Experimental studies of programmed learning have been reviewed by Beard (1976). Attributes of the successful programmes have been identified and an attempt was made to incorporate them. Reasons for the inefficiency in other programmes were identified and avoided.

Readings in research on distance learning offer guidelines for maximising the impact of the written word as a means of instruction (van den Bogaerde, 1987). Programmed instruction and programmed learning methods designed for computer-based training were investigated. These helped to identify learning objectives at different skill levels (Gagné and Briggs, 1974), to ensure efficient presentation of learning material (Baker and Schutz, 1971; Alexander and Blanchard eds., 1985), and to evaluate progress (Garner, 1966; Deterline, 1962; Smith and Moore (eds.), 1962; Lumsdaine and Glaser (eds.), 1960; van der Schee, 1989).

Student motivation studies (Entwistle, 1987) illustrate how learners advance with confidence as they master increasingly difficult tasks. Student self-assessment (Edwards, 1989) and peer assistance (Wilkinson, 1979) reduce the need for constant teacher–pupil contact. Techniques have been developed to make the self-scoring of exercises as efficient as possible (Anderson, 1989). Many of these aspects of instructional design were incorporated in the development of the map reading programme.

By the mid-seventies, sufficient empirical testing had been carried out to identify a set of principles for instructional design (Gagné and Briggs, 1974). Despite major developments in computer technology in the interim, these basic principles still apply in the development of instruction programmes. This view is confirmed by Taim (1984) who investigated the use of computer technology in management training in South Africa. He outlined the use of computers in education and illustrated how computer-based training techniques have advanced the frontiers of educational research. Although the cost of making computers available to all learners is prohibitive at present, ways of adapting these instruction principles to a manually driven teaching strategy have been attempted.

The geographic content of the programme was guided by research findings in the field of geography education. Geographical skills acquisition was investigated by Cox (1989). A model for the development and production of geography instructional materials produced by Dunn (1992) was useful. Guidelines for developing geography exercises which encourage productive learning, identified by Booth (1985), were followed, as well as the method of encouraging learning through reality-orientated problem solving based on geographic concepts as described by Okpala (1989a) and through geographic enquiry (Winter, 1992).

Computer programmes to teach map reading skills have been developed in the United States (Marran, 1990) and other countries. Although these developments have relevance for South African teaching strategies, the materials are unsuitable because of the unique, national character of topographic maps. The prohibitive cost of providing sufficient computers for schools at this time prevents the production of an interactive computer-based learning programme. However, the 'hard copy' programme in the form of work cards, answer cards and a learner's booklet has been designed following computer-based learning principles. If the resources could be found, the programme could be transferred to this medium with relative ease.

4.2 PRINCIPLES OF SELF-INSTRUCTION PROGRAMME DESIGN

'Instruction is the means employed by teachers, designers of materials, curriculum specialists, or other persons concerned in developing an organised plan to promote learning' (Gagné and Briggs, 1974, 210). The main thrust of this research involves the design, development, testing and evaluation of instructional materials to teach the reading of the South African topographic map.

The chief concern of the programme developer is to design instruction so that learning will occur efficiently, that is, in a minimum amount of time with maximum comprehension (or dexterity as the case requires). A primary task is to identify a starting point and then the best sequence of skills development to follow. A good foundation must be laid upon which a concept framework can be constructed. Learners also need the strategies to expand their existing framework, to develop the concepts which make up that framework and to link concepts together in novel ways. The present approach which leaves the choice of the topic sequence to the teacher's discretion or to the order of the chapters in the available text book is clearly not working as is demonstrated by the low marks achieved in matriculation exams.

Gagné and Briggs (1974) make a number of basic assumptions about instructional design. Efficient instruction is planned for the individual learner, has both immediate and long term goals, affects the learner's development in a positive way and is systematically designed based on the knowledge of how human beings learn. In comparing instructional design models and the theories upon which they have been developed, three basic elements emerge. Although named differently, they consist of the external factors affecting the learning situation, the content matter to be learned, and the internal factors which influence the learner.

Learning takes many forms, starting with recognition by an infant of its mother and continuing throughout life across a wide spectrum of abilities. The concern in designing a programme of instruction is with those aspects of learning over which an instructor has some control. Gagné and Briggs (1974) identify three external and five internal factors affecting the learning event which have an impact on how instruction should be designed. Each factor will be reviewed in relation to the design of map reading instruction

4.2.1 Three principles for accommodating external factors controlling learning outcomes

The external factors that control learning include all those distractions which can occur in the average classroom and include fellow learners, the teacher, the text books and learning aids. When designing a programme of self-instruction the designer has little control over distractions but he can exert some influence on the outcome of the learning incident itself by adopting three principles of learning: contiguity, repetition and reinforcement.

Principle 1 Contiguity

'This principle states that the stimulus situation to which one wants the learner to respond must be presented contiguously in time with the desired response' (Gagné and Briggs, 1974, 7). Teaching about a map skill must be accompanied by practice of that skill. Teaching the skill of identifying features using the map reference must be followed immediately by the opportunity to use symbols to identify features on the topographic map.

Principle 2 Repetition

'This principle states that the stimulus situation and its response need to be repeated, or practised, in order for learning to be improved and retention made certain' (Gagné and Briggs, 1974, 8). The rote learning of conventional signs and their descriptions, so often encouraged by teachers, has limited value. The type of repetition which is valuable in map reading is to offer learners repeated opportunity to use the reference list to answer a variety of questions relating to many different map extracts until they no longer need to refer to the reference list at all.

Principle 3 Reinforcement

'This principle states that learning of a new act is strengthened when the occurrence of the act is followed by a *satisfying state of affairs*' (Gagné and Briggs, 1974, 8, *italics* my own). Much debate surrounded Thorndike's original reward theory (1913). Over time it has been considerably modified and more recent studies (e.g. Keller, 1969, 1974) have proposed a variety of *satisfying states of affairs*. This instruction programme is based on the assumption that the positive feedback provided by the learners' self-assessment of tasks (which should gain high scores) may provide a sufficiently satisfying state to be rewarding. This assumption is strengthened by the practice in South African schools where marks (scores) are used as the basis of most evaluation and high marks are therefore likely to lead to an improved self image.

4.2.2 Five internal capabilities controlling learning outcomes

The three principles discussed above may help control the external learning factors. But, to design efficient instruction, the state of mind or internal processes of the learner also have to be taken into account. Although many factors internal to the learner could be considered, Gagné and Briggs (1974) stress the importance of five factors to consider when designing instruction. They refer to these internal factors as capabilities.

Capability 1 Information gathering

The capability of gathering factual information can be demonstrated by supplying a name or identifying a word from a list of possible alternatives which define or delimit its class. Information in words (verbal form) is essential to all learning, being the basis for building concepts, intellectual skills and cognitive strategies. Three kinds of learned information are identified: labels (names), facts and organised information. Gagné and Briggs (1974) identify facts as statements expressing a relation between two or more named objects, events or situations. Organised information is a larger body of facts which are associated with each other by their organisational structure such as the days of the week. The capability of gathering information would depend on the ability to read and remember.

A relevant example from the map reading instruction programme would be the learning of the names of the different kinds of roads. Because of the inconvenience of constantly referring to the reference list, learning to recall the names of the most frequently appearing road types would lead to greater efficiency.

Capability 2 Intellectual skills

Intellectual skills are those capabilities which make the human individual competent (Gagné and Briggs, 1974, 23). They categorise intellectual skills on the basis of their complexity. At the bottom of the hierarchy are those skills which can be specifically taught and internalised through repetition, whilst at the upper end rules are worked out by the learner and then internalised. The five levels of intellectual skills deal with discrimination, concrete concepts, abstract concepts, rules and problem solving.

(1) Discrimination - This is the ability to identify the characteristics of features and thus to discriminate between them. In this case it would refer to being able to discriminate between two similar but different conventional point symbols such as a communication tower and a windpump (appendix N) or between the brown line symbol for a contour and the blue line symbol for a perennial river. This ability is often assumed in older learners and is therefor not specifically taught at secondary school.

(2) Identification of concrete concepts - Concepts can be identified by their attributes. Identification consists not only of the name of a feature but also its overt meaning. In reading a map this would mean that the learner would be able to recognise the symbol and be able to label it (windpump). They would also associate the symbol and its label and with a visible windpump or a picture of a windpump.

(3) Definition and abstraction of concepts - The capability of defining a concept refers to the ability to demonstrate that learners understand not only its meaning, but can deal with the abstraction of the concept, its associated assumptions, actions and/or aspects. To expand the previous example, learners would demonstrate an awareness that windpumps pump water up from under the ground, which in turn implies an underground water source. Once on the surface, the water would be required for a particular use, such as stock farming. They would further be able to classify a concept: they could demonstrate that they understood that a windpump was one of a variety of means of acquiring water along with rivers, dams or furrows.

(4) Application of rules - The ability to use rules may or may not imply that the learner understands the rule. Children learn to speak before they understand the rules of grammar. Addition follows rules learned at primary school level. To assess the altitude of a point on a topographic map the learner can add (or subtract) the interval between contour lines from the nearest numbered contour. This task proves to be very difficult for many learners. Sometimes they need to be reminded that they already know certain rules which they do not transfer from one situation to another.

(5) Problem solving - The capability of generating higher order rules or applying two or more rules concurrently in order to solve problems is a major aim of the educational process (Gagné and Briggs, 1974, 45). This involves teaching pupils to think clearly. Solving a problem achieves a new capability and is often the crowning accomplishment of a great deal of learning. Some writers classify problem solving as a cognitive strategy while Gagné and Briggs classify the ability to use different cognitive strategies as a separate capability. For the purpose of this instruction

programme, problem solving will be classified as one of the five intellectual skills required for map reading.

Preliminary map interpretation, requiring a variety of cognitive strategies at a high skill level, is introduced in the last question of each exercise in the self-instruction programme.

Capability 3 Cognitive strategies

Cognitive strategies are the highest forms of intellectual skill because they make learners capable of governing their own learning, remembering and thinking behaviour. It must be accepted that learners manage their learning processes in different ways. When reading a map, some individuals will initially seek out symbols in bold or preferred colours, others establish patterns from linear symbols while some may move straight to the peripheral information such as the reference list.

Piaget (1955) links children's age (stage) with intellectual development demonstrated by their ability to perform increasingly complex logical operations. This implies that cognitive strategies place limits on the child's ability to solve problems because of their age. Gagné and Briggs argue that cognitive strategies develop out of specifically learned intellectual skills through the process of generalisation (Gagné and Briggs, 1974, 48) and further that 'the efficacy of an individual's cognitive strategies exerts a crucial effect upon the quality of their thought'. The suggestion that adolescents can be taught to improve their use of cognitive strategies is supported by the work of Büchel (1997).

Gagné and Briggs (1974) recognise two limits to intellectual development. Genetic factors, which education cannot influence, are likely to play a large part in creative thought. Second, the internally organised nature of cognitive strategies means that their development cannot directly be affected by conditions of instruction. They stress that it is by providing them with opportunities to think that people learn to think. The key is to present novel problems for which no direct solution has previously been outlined. Blaut and Stea (1971), Anderson (1995) and others were shown, in chapter two, to support this approach (see 2.3.3). Feuerstein et al. (1988) urge mediators to seek novel challenges for those in their care, so as to mediate new learning experiences. 'The general principal is that the kind of learning that may be required can be predicted not from age but only from the nature of the performance being sought as the objective of learning' (Gagné and Briggs, 1974, 50).

Capability 4 Attitude

The effect of an attitude is to 'amplify an individual's positive or negative reactions towards a situation' (Gagné and Briggs, 1974, 25). Operating in the affective domain (Bloom, 1956), we are all capable of forming attitudes. Due to lack of familiarity with maps and fear of their inability to cope with mathematical concepts, many learners adopt a very negative attitude towards topographic map studies. Unfortunately this negative attitude is often reinforced by their teachers who themselves lack confidence in their own map reading abilities.

Attitudes can be measured in terms of the choices of personal action taken by the individual. A direct and an indirect method of teaching attitude can be used. The direct method is by positive reinforcement: when a desired choice of action is selected 'success in some learning accomplishment is likely to lead to a positive attitude toward that activity' (Gagné and Briggs, 1974, 64). An indirect method of teaching attitude is through the agency of another human being, real or imagined, who acts as a role model. The persona, displaying a positive attitude, encourages and guides the learner towards improved performance. Such a persona, named Carto, has been used in the instruction programme and is introduced in chapter six.

Capability 5 Motor skills

A motor skill is the executing of some performance usually involving a part or all of the body. In some map analysis and interpretation tasks, certain information cannot be assessed from a topographic map until lines have been constructed. Motor skills are used to draw these lines, and to align a protractor to measure the angle of bearing between these lines, from one point to another. An important motor skill, involving hand/eye co-ordination required for map reading, is the ability to follow two different axes to find a location. Component skills can be taught and then integrated so as to improve rapidity and accuracy. Fortunately these skills are observable and can thus be improved quite easily through instruction and repetition.

Each of these five internal factors are capable of affecting the learning event. Each represents a category of behaviour that may be influenced by the instructional designer. As shown by the examples, when learning to read a map, learners can be instructed so as to improve their capability in each of these categories. Because none of the capabilities can be learned in isolation, multiple aims of instruction must be recognised. Programmes of instruction are often criticised for being too prescriptive but mapping out the learning structure need not prescribe how the student must learn (or be taught); it is simply a description of expected learning outcomes (Gagné and Briggs, 1974, 51).

4.3 TWELVE STEPS IN DESIGNING AN INSTRUCTION PROGRAMME

Based on the principles they had recognised, Gagné and Briggs (1974) recommend twelve steps in designing a programme of individualised instruction. Some of these steps have been referred to already; others will be dealt with in succeeding chapters but all are briefly summarised at this point. (A list of the 12 steps is included in appendix D for easy reference.)

Step 1 Analysis and identification of needs

The broad problem of poor mapwork performance and the need for improvement were dealt with in chapter three. Further justification for focusing attention on topographic map reading will be discussed in 4.4.1.

Step 2 Definition of goals and objectives

In 4.4.2 a hierarchy of component skills will be outlined, specific learning units identified and performance objective statements constructed and analysed.

Step 3 Identification of alternative ways to meet needs

Various strategies for teaching map reading have been discussed in chapter three.

Step 4 Design of system components

The three main components of the programme are the assessment component (both formative and summative), the map reading exercises including the questions and answers, and the support material which aids the learners when they begin the programme but is relied on less as skills improve (scaffolding). The final format used to combine these components were work cards, answer cards and a pupil booklet. Decisions regarding the number, order and layout of each one are discussed in chapter five. The local topographic map sheet must be identified for each school where the programme is to be used.

Step 5 Analyses of resources required, resources available and constraints

The acquisition of updated topographic map sheets, the selection of suitable map extracts and the use of photography for illustration purposes are described in chapter five which also briefly deals with the need for computer hardware, software and expertise.

Step 6 Action to remove or modify constraints

This step required much begging, borrowing and leaning on my friends to whom I am deeply indebted. Financial requirements were met initially from personal resources, later by a limited research grant and sponsorship, and in the last year of the research by the Chief Directorate of Surveys and Mapping. Reference grids for the map exercises were produced by a friend with computer aided design (CAD) skills. The services of the Academic Development Centre at the University of Bophuthatswana provided an initial layout design for a work card but the final prototypes of 52 work cards were designed and developed using the resources of the Chief Directorate: Surveys and Mapping. The master copies of the pupil booklets and 52 answer cards were laid out by another friend with desk-top publishing skills.

Step 7 Selection or development of instructional materials

The selection of map extracts, overlaying of a reference grid and the authoring of the map reading exercises and answers (for the work cards) are dealt with in chapter five. Authoring and illustrating the support material, including lesson texts (appendix E) and symbol explanations, is discussed in chapter six. Instructions for following the programme are on the front of the pupil booklet (appendix F).

Step 8 Design of student assessment procedures

Chapter five deals with the use of answer cards for self-assessment. These were developed concurrently with the exercises on the work cards. Performance criteria for completing the exercises were determined, and the progress graphs in the pupil booklet were designed to give learners and teachers immediate feedback.

Step 9 Field testing; formative evaluation and teacher training

Pre- and post-tests were drawn up to assess the impact of the programme on map reading performance (appendix H). A report on the pilot testing of the map reading exercises is included in chapter five. The learners' responses were used to evaluate and improve the programme while it was still at this formative stage. Teacher training needs were identified during the pilot test and classroom trial and are outlined in the concluding chapter.

Step 10 Adjustments, revisions and further evaluation

The completion of the prototype learning programme was guided by the findings of the pilot test especially the instructions to the learners. Confusion, resulting from the wording of some exercises, was identified and removed. Symbol explanations written during the early stages of the project were proof-read by a land surveyor and by a cartographer who had many years of compilation experience; both recommended further improvements which were incorporated into the support material.

Step 11 Summative evaluation

A full report on the school trial is included in chapter six.

Step 12 Operational installation

The objective of the research project is to develop a self-instruction method for learning to read the South African topographic map. The prototype resulting from this method has been developed and limited testing has been done. Recommendations for the further development and assessment of this method in schools are made in the concluding chapter.

The first three steps are dealt with in some detail in this chapter and the rest are dealt with in the remainder of the research report. Gagné and Briggs (1974) stress that, although each of the above steps is important, constant revision of previous steps may be necessary when viewed in the light of developments at later stages in the planning.

4.3.1 Analysis and identification of needs (Step1)

Having accepted that mapwork performance is poor and that there is a need to address the problem, a specific area of intervention must be selected. The task of doing topographic mapwork must be analysed on the basis of outcomes, and the competencies required to achieve each outcome must be identified.

The final core syllabus of the Transvaal Department of Education (undated) referred to the general geographic techniques required in the tenth year of schooling under the sub-heading: reading, analysis and interpretation (of) the 1:50 000 topographic map of South Africa. The list of topics included: direction and bearing, horizontal distance, contours, landforms, cross-sections, gradients and vertical intervals, vertical exaggeration and intervisibility, conventional signs and cultural landscape. No clear distinction was made between reading, analysis and interpretation. In other syllabus documents consulted there were no such lists of skills, only the injunction that *appropriate* geographical techniques are essential. Neither the topics listed above nor the inappropriate sequence of skills presented in many textbooks (discussed in section 3.7.3) provides guidance in selecting a starting point for addressing learners' needs.

After examining topographic mapwork tasks, analysing their component sub-tasks and identifying the skills required to perform these tasks, a branched rather than linear programme of instruction is proposed. In figure 4.1 arrows are used to indicate the process of task analysis which operates backwards from the required outcome of instruction. The result of the analysis is a proposed framework that could be used to present instructional material for a range of topographic mapwork competencies up to and including the calculation of gradient (task level 4). Beyond this level, spatial data can then be gathered from the map to analyse and interpret the distribution of natural and constructed features of the landscape.

Figure 4.1 Task analysis, working backwards from the desired outcome

TASK LEVEL 4
GRADIENT CALCULATION

⇩
depends on the capability of
⇩

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

⇩
which depend on the capability of
⇩

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

⇩
which depend on the capability of
⇩

TASK LEVEL 1
READING CONVENTIONAL SIGNS
THEIR IDENTIFICATION, RECOGNITION AND COMPREHENSION
(a starting point)

Six sub-tasks have been identified which need to be completed before gradient can be calculated. The numbering of the tasks in figure 4.1 does not indicate levels of difficulty but rather the order in which tasks must be completed to reach the desired outcome. Before the gradient of a slope can be calculated (task level four), the distance between two points on the slope must be measured. The difference in height between the two points must also be found. The relative difficulty of these two tasks (both level 3) is immaterial, but both must be accomplished before the gradient can be calculated.

The position of the two points must be found before either of the above tasks can be accomplished. The instructions for finding points on the map may be given in the form of their co-ordinates, the bearing from one to the other or a description of the direction of one to (or from) the other. The learner must be able to perform all of these level two tasks. The order in which they receive instruction for these tasks is immaterial as is their perceived degree of difficulty. It could be argued, for example, that it is much easier to describe direction than to calculate bearing. Because there is no reference grid on the topographic map to guide learners, the location of individual map symbols may be given by any one of these methods and learners need specific instruction in using each one.

Before the task of locating symbols can be accomplished, the symbols have to be identified, recognised and understood (task level one). The reference list provided on the map should make this task easier. To improve performance, learners need to reduce their reliance on this list as they learn to recall the label of each symbol and to build up their own framework of associated concepts.

The performance of topographic mapwork tasks is improved by the understanding of the concepts represented by the map symbols. Sound comprehension lays the foundation for the more advanced concepts required for task levels two, three and four (figure 4.1). Because the performance of tasks at all levels depends on map reading, improvement at this level was recognised as the most important need which should be satisfied in order to improve mapwork performance. Although the current research effort is focused on map reading, the need to develop instruction for all task levels is recognised, eventually including analysis and interpretation.

In the next chapter the factors which led to the choice of four distinct topic areas and subsequent sub-topics is discussed in some detail. It is sufficient here to indicate that the topics of **landscape, urban settlement, rural settlement and transport** were selected to divide the instruction programme into manageable units. This also ensures that a representative range of conventional symbols and terms used on the topographic maps is covered in order to develop the concepts required for reading maps with understanding.

4.3.2 Definition of goals and objectives (Step 2)

The only way in which a teacher knows whether the learner is capable of any kind of skill is to observe performance of the skill and, further, it is in providing the opportunity to perform the skill that it is taught. The objective of efficient teaching should therefore be the acceptable performance of skills. The best way to design instruction is to work backwards from the outcomes it is expected to have (Gagné and Briggs, 1974, 19). A crucial stage in the planning of instruction is deciding on the outcomes or goals of the instruction. This decision must in turn focus on the educational needs of the learners. 'When education goals are matched with education needs, the ideal conditions exist for the planning of a total education programme' (Gagné and Briggs, 1974, 31).

Considerable time was spent in defining performance objectives (outcomes) which would be so 'clear and transparent - that assessors, assessees and third parties should be able to understand what is being assessed, and what should be achieved' (Wolf, 1995, 2). The criteria proposed by Ten Brink (1974) for clear performance objectives are that they should indicate an action, on an object, in a specific situation, and also the tools required and the constraints within which the performance of the learned capability is to be carried out. Figure 4.3 illustrates the analysis of the statement of performance objectives for the topic **landscape** (figure 4.2). The same format was used for all four topics although the specific details were slightly different.

Figure 4.2 Statement of performance objectives for the lesson on **landscape**

Learners must be able to locate and identify conventional signs associated with landscape on the 1:50 000 topographic map of South Africa. They must be able to relate the symbols to the landscape-related concepts that they represent. They must demonstrate their comprehension of these concepts by correctly naming, describing, classifying and/or comparing landscape features in response to ten questions with an accuracy of eight out of ten.

Figure 4.3 Analysis of statement of performance objectives for the topic **landscape**

Action	Locate, identify, answer questions
Object	Landscape features as represented by map symbols
Situation	Using 1:50 000 South African topographic map sheets
Tools	Reference list, alphanumeric grid, illustrated symbol explanations, lesson text
Constraints	Self-study, little if any guidance or discussion
Learned capabilities	Location of symbols using hand/eye motor skills. Discrimination, identification and comprehension of symbols. Classification and/or comparison of landscape features

The statements of performance objectives, devised to guide instructional programme development, were worded slightly differently and presented as learning objectives on each work card (figure 4.4). The statements are learner focused, written in an action-orientated style and give a clear indication of which capabilities are to be maste. .d.

Figure 4.4 Learning objectives for each topic

RURAL SETTLEMENT

When you have mastered this topic you will be able to
- identify different rural settlements on the topographic map,
- describe the surrounding land use, and
- suggest why people started settling in the area.

URBAN SETTLEMENT

When you have mastered this topic you will be able to
- identify different urban features on the topographic map,
- describe the characteristics of different parts of an urban settlement, and
- compare different urban land use zones.

TRANSPORT

When you have mastered this topic you will be able to
- identify and name the types of transport shown on the topographic map,
- describe the differences between them, and
- suggest reasons why they are used.

LANDSCAPE

When you have mastered this topic you will be able to
- read the height clues on topographic maps,
- identify different slopes, and
- describe different types of landscapes.

Having decided on the outcome required from the learners, the next step is to word the instructions so that learners know what is required of them in order to demonstrate that they have developed the capability intended by the instruction designer. In figure 4.5 human capabilities (as identified by Gagné and Briggs (1974) and discussed in section 4.2.2) are listed on the left while on the right are examples of verbs used in the formulation of the relevant learning objectives.

Figure 4.5 Instructions used to develop and assess capabilities

CAPABILITIES	EXAMPLES OF INSTRUCTION
1 Information gathering	list, state, name
2.1 Discriminating	distinguish between
2.2 Forming concrete concepts	identify, name (the map symbol)
2.3 Using abstract concepts	classify (the feature)
2.4 Applying a rule	calculate
2.5 Solving a problem	any verb used to imply the generation of a solution by synthesising applicable rules (e.g. suggest)
3 Adapting cognitive strategy	any verb used to imply the origination of a solution in an unfamiliar context (e.g. visualise)
4 Improving attitude	choose (course of action)
5 Using a motor skill (hand/eye)	locate

In order to ensure that the instruction is designed to provide a step by step progression from one level of ability to the next, a learning hierarchy is identified. The lesson on landscape is again used as an example. Each mapwork exercise comprises ten questions. By grading these questions according to their level of difficulty, (see figure 4.6) the learners' levels of ability can quickly be assessed by examining the answers to the questions which they consistently get wrong. If teachers are informed about which capabilities are developed and assessed by which question numbers, then they can offer mediation at the appropriate level. By indicating the prerequisite skills, those learners who cannot answer even the first few questions correctly would soon be identified. They could be taken off the programme and offered the appropriate mediation, giving them the ability to continue later with some hope of improvement. The mediation may vary between supplying a magnifying glass where eyesight is weak, checking language proficiency, explaining terminology or clarifying instructions.

Figure 4.6 Learning hierarchy and question numbers for exercises on **landscape**

Demonstrate comprehension by answering questions relating to identification, description or visualisation of landscape features.
10

⇧

Classify feature by relating it to concepts of relief and drainage as well as cultural landscape
7, 8, 9

⇧

Identify landscape feature by naming feature
4, 5, 6

⇧

Discriminate between landscape symbols on the basis of colour, pattern and shape
2, 3

⇧

Locate symbol using alpha-numeric grid (motor skill)
1

⇧

Prerequisite skills

- Ability to read and comprehend English language as a medium of instruction
- Average eyesight enabling learner to read small print and distinguish colours
- Adequate range of vocabulary to answer questions in English

The formula described in figure 4.6 was applied in the development of each exercise in the landscape section and with slight adjustments to the wording to all fifty-two exercises in the programme. This was no simple matter and evolved, over time, from much initial trial and error. The process is described in chapter five which deals with steps four to nine of the design and development process as identified by Gagné and Briggs (1974) and included in appendix D.

4.3.3 Identification of alternative ways to meet needs (Step 3)

In chapter three various reasons for poor mapwork performance were discussed which suggest that current attempts to meet the mapwork learners' needs are not successful in all cases. In chapter five my own unsatisfactory attempts to improve mapwork are briefly described. The ideal alternative described in the opening paragraph of this chapter is unattainable. A computer-based learning programme could possibly be designed to meet learners' needs but the schools where the mapwork performance is poorest would be unlikely to have access to the hardware necessary to use the programme. The present attempt to develop a self-instruction programme for map reading is the alternative that has been identified.

Having described the first three of the design steps proposed by Gagné and Briggs (1974), the basic framework of the self-instruction programme for learning to read the South African topographic map has been established. The design itself evolved as steps were revised in the light of newly completed sections, or in some cases as new research came to light during the long period of time over which the programme was developed. From step four, the design of the system components, progress was dictated more by the development of the programme than by its design. The following chapter picks up the story.

CHAPTER 5

DEVELOPING A SELF-INSTRUCTION PROGRAMME FOR MAP READING

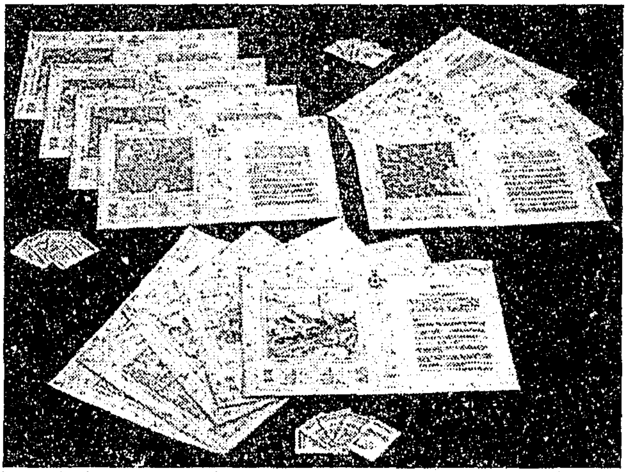
My development of exercises for improving map reading started long before research revealed options such as the twelve steps in designing an instruction programme, outlined by Gagné and Briggs (1974). In this chapter an attempt is made to trace the development of the instruction materials from a chronological perspective that does not easily dovetail into the twelve-step plan discussed in the last chapter and outlined in appendix D. In many aspects, this plan became a check list against which to continue the development of the materials. The component list (figure 5.2) includes some items which were envisaged before research into the development of a self-instruction programme even began (such as illustrations for the map symbols) but which were realised only long after the pilot test had been conducted. Some components were developed only after the pilot test had made the need for them obvious. Although reference is made throughout this chapter to the twelve steps proposed by Gagné and Briggs (appendix D), the text does not follow the order of the steps.

5.1 DESIGN AND DEVELOPMENT OF SYSTEM COMPONENTS (STEPS 4, 5, 6 AND 7)

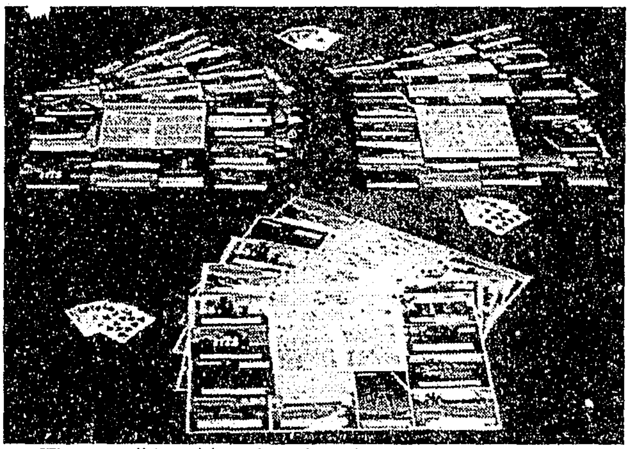
As mentioned in the last chapter, the three main procedural components of the self-instruction programme are: the map reading exercise component, the assessment component and the support material component. As soon as development for each component started (step 7), the initial design (step 4) had to be adapted repeatedly to meet the restrictions and opportunities presented by what material and other resources were available (steps 5 and 6). In order to carry out the procedures needed for the self-instruction programme to be effective, the physical components developed were work cards, answer cards and a pupil's (or learner's) response booklet. Figure 5.1 illustrates examples from the prototype of the programme.

Figure 5.1 Three components of the self-instruction programme

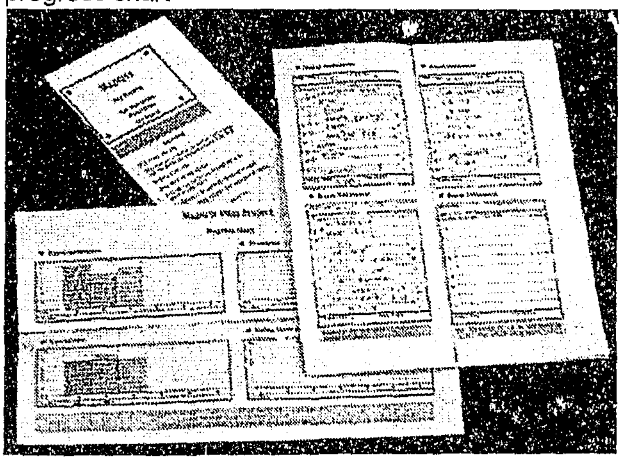
a. Work cards and answer cards for one theme (front)



b. Work cards and answer cards for one theme (back)



c. The pupil booklet showing the front cover, answer sheets and progress chart



The three components were made up of a number of items which all had to be completed before the prototype of the self-instruction programme could be tested. Figure 5.2 lists all the items that make up each component; only those that have been ticked were ready for the pilot test and are thus dealt with in this chapter. Appendix C includes samples of items two to six plus ten and eleven.

Figure 5.2 Component breakdown into 16 items (ticked items ready for pilot test)

COMPONENT	SUB-COMPONENT	ITEM
WORK CARDS - 52	FRONT	1. Playing card reference ✓
(52 x laminated,		2. Map extract ✓
approximately A3 cards)		3. Alpha-numeric grid ✓
		4. Reference list/map key ✓
		5. Introductory text ✓
		6. Ten graded questions ✓
	BACK	7. Lesson title
		8. Lesson objective
		9. Lesson text
		10. Selection of 10 illustrated symbol explanations
ANSWER CARDS	FRONT	11. Ten answers ✓
(52 x Playing cards)	BACK	12. Playing card reference ✓
PUPIL BOOKLET	FRONT COVER PAGE	13. Space for pupil's name
(16 x A5 Pages)		14. Instructions (16 steps)
	ANSWER SHEETS (2 per page)	15. Six answer sheets for each theme (total 24)
	GRAPH SHEETS	16. One progress graph per theme (4)

5.1.1 Early attempts to design 1:50 000 topographic map reading tasks

As a novice geography teacher, teaching map reading at secondary school level, I followed the conventions of my predecessors. However, I found that neither lessons about the focal length of cameras (designed to take vertical aerial photographs), nor explaining the ancillary information in the map margin, nor instructing learners to copy out of the reference list, helped to improve map reading skills. It became clear that the only way to teach mapwork was to set the learners map reading tasks. Without sufficient text books or maps, this was no easy matter. Using an analogy with another skill, tennis, discussing the way a tennis racket is strung and how tennis balls are manufactured does little to improve the individual's tennis skills.

A number of exercises were devised focusing on different geographic themes such as narrow, V-shaped valleys, U-shaped valleys and wide flat floodplains. These proved reasonably successful with senior pupils but were of little value at the more junior level because these geomorphology concepts had not yet been developed. A system was needed to introduce the novice map readers to the symbology of the map in a more organised way and it was decided that a series of map exercises was required focusing on map reading which would cover as many of the map symbols as possible. Each symbol should be fully explained and illustrated. There was a conviction from the outset that only full-colour maps should be used. The distinction between symbols on photocopied extracts is not possible and leads to confusion, increasing the perceived difficulty of map reading. (Unfortunately this practice is widespread in under-resourced geography classrooms.) Further it was decided that all map sheets, to be used for the map reading exercises, should be drawn to the specifications on the Mowbray style chart for the South African 1:50 000 topographic map (Chief Directorate: Surveys and Land Information, 1987).

5.1.2 The alpha-numeric grid

The absence of a grid of lines on the 1:50 000 topographic map of South Africa is a major drawback for the novice map reader (see discussion in 3.2). For someone unfamiliar with the conventions of map use, it cannot be expected that they will be able to locate a feature on a map using co-ordinates or bearings. Describing the location of features using direction is confusing when the concept of direction itself, and how it is represented on the flat surface of a map, are unfamiliar.

In order to set questions testing the understanding of information read from the map it was necessary to impose a grid that could easily be used to locate the feature(s) referred to in the questions. A grid of lines approximately one-half minute of latitude by one-half minute of longitude was used which neatly covered each map extract with 10 x 10 (100) blocks. The grid was labelled alphabetically for each row and numerically for each column. Attempts to draw this grid by hand onto the selected map extracts proved unsuccessful. Various attempts at fixing the grid, printed on a transparent sheet, over the map extract failed. The best results were achieved when the grid was printed out (using a computer-aided design programme) and the map extract was colour photocopied onto the same page. The assistance of kind friends and the generous sponsorship of the colour photocopying are gratefully acknowledged.

It must be stressed that without this alpha-numeric reference grid on the map extracts, the development of the self-instruction programme would have been impossible.

5.1.3 Map symbols, the alphabet of map reading

Just as the alphabet is the starting point in learning to read text, the map symbols must be recognised and understood when learning to read maps. Unlike the alphabet, there are far more than 26 map symbols. The key or reference list on each map sheet has 42 entries (appendix N). The task of explaining and illustrating each entry on the list did not seem too daunting until closer inspection revealed that many entries were in fact combinations of symbols. When each of these was listed separately the list was 63 entries long. Some symbols are used to show more than one feature, such as orchards and vineyards, each of which appears quite different to an observer on the ground. The question of how many items of map information (symbols) to include in the learning programme was further complicated by the fact that many descriptive words and terms are used instead of symbols, for example, sewage works and golf course. The meaning of these terms may not be clear to learners at lower grades or in remote rural areas or to those for whom the language of the map (English or Afrikaans) is not their mother tongue.

Eventually the explanation list extended to 88 items. A means had to be found to include the most commonly used descriptive words, and dot, line and area symbols in the programme. A selection of map extracts based on a predetermined group of symbols was considered. The only way that this would be possible would be to make the maps 'to order'. This was soon ruled out as the task of creating valid landscapes was impossible. The only way to ensure that learners would encounter a specific range of symbols in their map reading tasks was to group symbols in some way and instruct learners to select map exercises from each of the groups. Although it was not yet absolutely clear how the symbols would be grouped, the decision was made to purchase a small range of map sheets and make a start.

In 1990 an approach to the Chief Directorate of Surveys and Land Information (as it was known at the time) for assistance led to most helpful correspondence with an ex-geography teacher who was on the map sales staff. Mr A. Rimer had handled requests and inquiries from teachers and pupils for many years and had selected, in response to their needs, a list of topographic map sheets to illustrate specific geographical phenomena or themes (Chief Directorate of Surveys and Land Information, 1993). This list became a valuable starting-point for map selection, especially as he had indicated those sheets that had been produced according to the new specifications. A start-up set of 23 maps was ordered.

Two factors influenced the size of each map extract that could be used. The extract and the symbol reference list should be able to fit on a standard sheet of paper for ease of reproduction and storage. A grid should be printed on the map so that the location of specific features could be given easily. Using extracts of a topographic sheet measuring 5' x 5' (five minutes of latitude by five minutes of longitude) left enough space on an A4 page for the surrounding alpha-numeric labels for the grid, for the reference list (or map key) and for other ancillary information (appendix C.1).

5.1.4 Map extract selection

1 916 sheets make up the 1:50 000 topographic map of South Africa. The 23 map sheets that I had acquired constituted a very modest sample. An attempt was made to group the map symbols according to colour. The maps were scrutinised and 5' x 5' extracts were identified where there was a predominance and variety of symbols in a single colour such as green, blue, red, black and brown. Symbols were divided into six groups, three groups of black signs, one group each of green, brown and blue and the few red signs were joined to the other groups. In attempting to prepare exercises based on such groups, it soon became clear that there was no conceptual link between the symbols that were grouped together, for example, brown contour lines and brown secondary roads.

It was in trying to fit the red map signs into the other groups that the idea of using geographic topics or themes was considered. Symbols were grouped into topic areas irrespective of colour. Various combinations were tried and the grouping eventually selected: **urban settlement, rural settlement, landscape** and **transport** gave the best distribution of symbols per group. These themes also made it possible to find map extracts which contained these groups of symbols near to each other. Cross-referencing between these four conceptual constructs (themes) made it possible to prepare questions and symbol explanations which developed and linked concepts. For example, in order to make transport possible, there is a need for a *cutting* along a *railway* due to the relief of the landscape shown by the *contour lines*.

5.1.5 Number of work cards

Once the four themes had been selected to include an even spread of symbols, two further parameters needed consideration. How many work cards would be required to meet the needs of learners in a classroom, and how many map extracts were needed to provide a variety of stimulating exercises for the four themes? There was also a concern that the range of map reading exercises should be representative of South Africa's natural and cultural diversity. The 23 map sheets purchased so far were not all suitable. Some were of remote areas where there was insufficient variety in the symbols to be found in any 5' x 5' extract. When more than one extract was taken from the same sheet the repetition made it difficult to set interesting and engaging questions for the exercises.

To be useful in the classroom, sufficient work cards were needed for each pupil to have one to work on. There would need to be enough spares so that those working faster would be able to select another work card when they had finished the current one. Accepting that 30 to 40 pupils is considered a reasonable class size, it was estimated that at least 25% of the cards (7 to 10) should be available for circulation at any one time. Thus it was decided that fifty or more work cards should be sufficient to meet the needs of a classroom of learners.

A desire to give the map reading programme a game-like quality, the selection of four themes, and a requirement of 50 or more work cards, led inevitably to selecting the organising structure of a standard pack of playing cards. This dictated the total number of 52 cards and made it possible to identify the four geographic themes with the four suits of playing cards. The link decided on was Hearts for **rural settlement** (love of the rural home), Clubs for **urban settlement** (city entertainment), Diamonds for **transport** (arterial route marker), which left Spades for **landscape**.

After the development of some initial exercises based on each of the theme groups, more maps were required. An interview was granted with the Chief Surveyor General for South Africa, at that time Mr K. Lester, to discuss the research at his office in Mowbray, Cape Town. He supported the concept, invited me to select as many maps were required and he donated them. His support is gratefully acknowledged. A considerable amount of time was spent perusing all the map sheets which had been printed using the new symbols and selecting a wide enough variety to use for all 52 exercises, 13 for each theme.

5.1.6 Playing cards

At this stage there was still a random element in the grouping of the symbols on each map extract. There seemed to be no way to ensure that learners would encounter all the symbols in each theme unless they increased the number of work cards they completed. By including, on every work card in the theme, a reference to the most common map symbols, it could be guaranteed that these at least would be encountered. It was possible that this repetition might introduce an undesirable element of boredom. Preparation of exercises continued, however, with each new exercise being allocated the next consecutive number in each suit.

As the work progressed, subgroups of symbols became evident depending on the nature of the mapped area. Closer examination (and a little manipulation) made it possible to identify three symbol subgroups within each theme. Common symbols representative of each subgroup could be used on each work card in the subgroup. By instructing the learners to select one work card from each subgroup, the chances of encountering the majority of the most common symbols could be guaranteed. Each of the three subgroups of work cards was allocated a different series of playing card numbers as illustrated in figure 5.3.

Figure 5.3 Theme subgroups linked to playing card suits and numbers

THEMES	TRANSPORT	URBAN SETTLEMENT	RURAL SETTLEMENT	LANDSCAPE
SUITS	DIAMONDS ♦	CLUBS ♣	HEARTS ♥	SPADES ♠
Picture cards (Ace, Jack, Queen, King)	Unusual types of transport	Large cities	Subsistence Farming	Plains
Odd numbers (3, 5, 7, 9)	Focus on railways	Industrial areas	Other economic activities	Mountains
Even numbers (2, 4, 6, 8, 10)	Focus on freeways	Small towns	Commercial Agriculture	Valleys

This meant that the numbering system of all the completed work cards had to be changed. Where too many exercises had already been written for one subgroup, some questions had to be rewritten. In some cases new map extracts had to be selected and replacement exercises drawn up. This was the first of many adjustments and revisions of the programme (step 10).

Work progressed with the exercises for Clubs, Hearts and Spades as they could be based on the map sheets that had been selected. Problems arose with the map selection for exercises on the **transport** subgroup dealing with freeways (Diamonds, even numbers). At the time when the second map selection was conducted most of the maps available using the new specifications, were of rural areas. Fortunately, during the intervening period, the production of new specification maps of the more densely built-up areas, where freeways are necessary, had progressed rapidly. The final group of map sheets was selected and purchased from the Government Printer in Pretoria. Appendix B illustrates the distribution of map sheets used for the self-instruction programme.

5.1.7 Constructing the exercises

Although there had been an initial attempt to set exercises on the randomly selected map extracts and later on the colour specific symbol groups, they had not followed a pattern. Once the theme groups had been decided, work on the exercises became more focused. So that the learners would have a variety of maps to read, many short exercises would be better than fewer long ones. To keep the self-assessment and recording of progress as simple as possible, it was decided that an exercise would consist of ten questions on each map extract. Each question referred to a specific map symbol or group of symbols. Questions were phrased so that only one possible answer could be correct. Exclusive use of multiple-choice questions was ruled out, due to the high element of chance in selecting the correct answer, but some multiple-choice questions were used so that, where necessary, a specific answer could be selected. Initially questions were not ranked according to difficulty. Questions for the first two themes had been completed, before the possibility of using the ranking of questions as a diagnostic tool was considered.

In chapter four cognitive levels proposed by different writers were matched with the specific task levels required for map reading (refer to figure 4.6). It was recognised that a far more efficient product could be developed if the order of the question types was regulated. An attempt was made to match cognitive levels with question numbers so that the first questions tested lower cognitive levels and the last questions higher cognitive levels as illustrated in figure 5.4. Although this could not be adhered to strictly in each case, the questions were graded as closely as possible to this formula. If learners consistently answer the same type of questions incorrectly, this gives the teacher an idea of where mediation is required.

Figure 5.4 Link between question numbers and cognitive levels

The levels of difficulty are linked with the question numbers so that

- Question 1 tests hand-eye motor skills to locate a specific symbol or word,
- Questions 2, and 3 test recognition of the differences between symbols and the link between the symbol referred to in the question and its referent in the list below the map,
- Questions 4, 5 and 6 test the skill of identification of the 'real world' feature represented by the map symbol,
- Questions 7, 8 and 9 test the learner's ability to link the feature into a broader conceptual framework or class, and
- Question 10 tests the learner's comprehension of the function, importance or development of the relevant feature or structure and often requires visualisation.

All the completed exercises were revisited, some questions were dropped or adapted and new questions were added (step 10). Reworking the 260 questions for the 26 completed exercises was time-consuming and a low point in the development of the programme. Once completed, however, preparing the remaining 260 questions to complete the map reading tasks progressed well. Principles of *Editing for Language Accessibility* (Publishing Training Project, 1994) focused attention on the need for clear instructions and uncomplicated language to promote learning.

5.1.8 Symbol explanations and final exercise restructuring

In the earliest stages of the research it was decided that learners should have available a full explanation of all the symbols and descriptive terms used on the 1:50 000 topographic map. The text for these explanations should include the name of the feature or structure currently used in the map key, a description of its appearance and its use and/or importance.

Once the 520 questions had been completed for the 52 work cards, it was time to select a sample of ten symbol explanations for the support material on the back of each work card. It was decided to explain symbols referred to in either the questions or the answers, whichever would be most helpful to the learners. The allocation of ten symbol explanations per work card was done with some difficulty. Some symbols were referred to in more than one of the ten questions in an exercise leaving less than ten to explain while on some work cards the difficulty was selecting only ten from the variety of symbols used in the questions. Once the allocation had been completed, an analysis of the symbols to be explained on each work card revealed that some symbols were explained repeatedly and others not at all. This was a major setback in completing the programme.

Two problems resulting from the unsatisfactory explanation of symbols were boredom due to repetition and misunderstanding as a result of lack of information. Careful consideration of a solution to these problems highlighted a third. By presenting the symbol explanations in the same order as the questions to which they referred made finding the answers too easy. Competence could thus be indicated by a high score, but without comprehension of the relevant concepts. It was decided to introduce an element of chance by placing the explanations in a random order and providing explanations of some symbols that did not appear in an exercise.

The only way to remove the imbalance in the symbol representation was to go back and examine each map extract, find symbols which had been underrepresented in the questions, and substitute questions on a variety of symbols for those that had been repeated. In some cases the frame of the map extract had to be shifted, losing some symbols so as to include others. Many new questions were written to accommodate the improved spread of symbol representation. Having to restructure all 52 exercises once again was extremely time consuming. Using the cognitive levels established for questions one to ten, the fine-tuned grouping of symbols into twelve subgroups, and a specific list of symbols which had to be included, made the task easier. This was the third major revision of the programme (step 10).

5.1.9 Introductory texts for map exercises

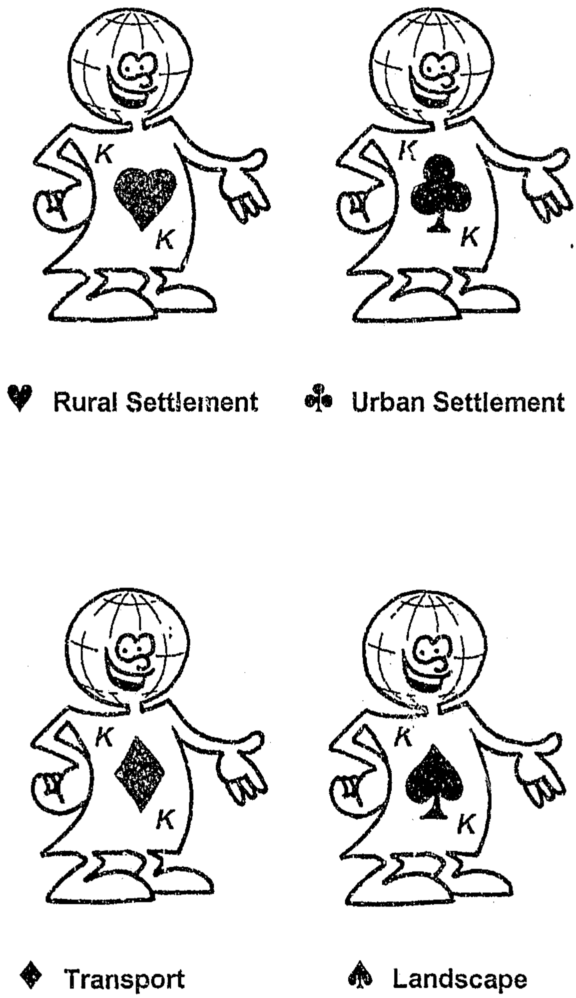
Findings in reading research suggest that comprehension of new concepts is enhanced if an existing cognitive construct can be activated (Kitao, 1989). If this is true for reading text, could it also be true for reading maps? Brief introductory texts for each map reading exercise were researched and prepared (Mayhew, 1986). These introductions describe the map area and where it is in South Africa, and discuss why it has been selected as an example of the theme. Carto (figure 5.5) introduces the map to the learner in such a way as to create a positive attitude to the learning activity. The style of writing and contents of the text are intended to stimulate interest in the map area (appendix C.2).

5.1.10 Programme identity

Because I had to approach so many people in my search for materials and resources to develop the programme, it became necessary to give it an identity. The name MAPTRIX evolved by combining the word *matrix* (or grid), which makes features easy to find on a map, with the word *map* and a pun on card *tricks* (which are fun). The product envisaged as the outcome of the research is the Maptrix *Kit* of teaching materials, reinforcing the idea of a game

Although no self-instruction programme can truly mediate learning (Feuerstein, 1980), the concept of a teaching persona was adopted to help develop a positive attitude to the learning situation. In the role of mediator, the character talks to the learner, making it possible to adopt an interactive and personal style in the wording of the questions and instructions. A conscious attempt was made to invite the learner into the mapped area so as to aid visualisation of the landscape. A teacher character with whom the learners could identify, based on the joker in a pack of cards, was initially designed. Later a cartoon-type character, named *Carto*, from an abbreviation of the word cartographer, was developed for the MapAware Project. The joker was replaced by the friendly Carto character who was used as the teacher and was also 'dressed' to identify each theme (figure 5.5). Carto is now an integral part of the Map Awareness and Map Literacy Project of the Chief Directorate of Surveys and Mapping.

Figure 5.5 Carto wearing the suits to identify each theme



5.2 THE PILOT TEST (STEPS 8 AND 9)

Before all the items for each component of the self-instruction programme had been completed, an opportunity was found to run a pilot test on the most important part of the programme, the map reading exercises. All the materials required for the front of each of the 52 work cards (items number one to six in figure 5.2) as well as the answers (item 11) were prepared on A4 pages. For each work card, two A4 plastic sleeves were stapled together, booklet style. Into the front 'cover' was placed a playing card to identify the exercise; side by side on the inside 'pages' were the map extract and the exercise consisting of the introduction to the map area and ten graded questions. The answers were on the back 'cover'. Answer sheets, which doubled as proof-reading reports, were drawn up (appendix G).

Although all the original questions had been proof-read by the research supervisor, the repeated adjustments to the exercises necessitated a further proof-reading. It was necessary to check textual errors as well as the accuracy of the grid references, both those in the questions and in the answers. Concurrently with the pilot test, the materials were proof-read by an experienced cartographic proof-reader. The purpose of the pilot test was two-fold in that all the exercises were subjected to proof-reading and the proposed administration of the self-instruction programme could be tested for ease of use and the clarity of the instructions (given verbally) could be assessed.

An instrument had to be designed to test the hypothesis that the self-instruction programme, even in this incomplete state, could improve map reading performance. The sample map on the Mowbray Style Chart was used as a test map for a pre- and post-test. It was scanned, an alphanumeric grid was placed over the map and colour photocopies were made (appendix H.1). Twenty-five pairs of questions were drawn up with the specific aim of making them equally difficult. The twenty five pairs of questions were not numbered according to cognitive levels, but they tested recognition, identification and comprehension of map symbols in random order. Every attempt was made to focus attention on similar signs, whether they be line, area or point symbols, and to make the instructions equally clear and specific. One set of questions was labelled Test S (start) and the other, Test E (end). Each answer was worth one point to simplify scoring (appendices H.2 and H.3).

5.2.1 Participants

Eleven pupil survey officers, newly appointed to the Chief Directorate of Surveys and Mapping in Mowbray, Cape Town, followed the Maptrix programme as part of their work place orientation. Nine of these recruits had been selected from a large number of applicants for these training posts. Two had been offered training as a service to the Namibian Survey Department. As with all new staff appointments, the pupil survey officers had been selected according to equal representation criteria and included candidates from groups formerly underrepresented on the staff of the organisation. Candidates ranged from 20 to 33 years of age and included five males and six females. Judging from their applications for training and employment in this Chief Directorate, all had an interest in the field of land information whether in survey or cartography; some already had relevant work experience.

The pilot test was conducted over the period of one week (14 to 18 July 1997) on the premises of the Chief Directorate of Surveys and Mapping under the auspices of the training department. A suitable venue was made available and on the first day the pupil survey officers and representatives of management were addressed. The planned procedure was outlined. A pre-test was to be conducted the following day after which participants would start work on the exercises. This was to continue for three hours each afternoon with a post-test on the Friday. After discussing the motivation for and development of the learning programme and the hypothesis and assumptions to be tested, the candidates filled in a personal questionnaire.

Because it was necessary to check whether the S Test and the E Test were of equal difficulty, one group completed the S Test as a pre-test and the E Test was later used as a post-test. The other group wrote the tests in the reverse order. The division of the pupil survey officers into two groups could not be done without due care. The group was too small to use random selection to divide the sample population in half, so an assessment of their potential map reading ability was devised based on certain assumed advantages (figure 5.6).

Figure 5.6 Map reading advantage assessment

Maturity advantage

Advantage was assumed on the basis that more mature learners may have had more opportunity to use maps and would perhaps grasp the mapped concepts more easily.

Age 22 or < (born after 1975)	*0*
Age 23 – 27 (born between 1970 and 1974)	*1*
Age 28 or > (born before 1969)	*2*

Language advantage

Because the materials are in English, a point was allocated as a language advantage if the candidate had English as a home language.

English as only home language	*1*
English as second home language	*0,5*
English not spoken at home	*0*

Matric subject advantage

Map reading is an important component of the geography syllabus at high school and candidates having taken this subject would have an advantage over those who had not. The attainment of higher symbols (A, B or C) was assumed to indicate a better grasp of the geographic concepts which are needed for map reading. Mathematics and other science courses were also assumed to be an advantage because of their analytical approach or similarity in subject matter. Apart from the subjects mentioned, an A symbol in any course was identified as an advantage.

Geography	*A, B or C*	*3*
Geography	*D, E or F*	*2*
Geography	*< F*	*1*
Mathematics	*A, B or C*	*2*
Mathematics	*D, E or F*	*1*
Science	*A, B or C*	*2*
Science	*D, E or F*	*1*
Biology	*A, B or C*	*1*
Biology	*D, E or F*	*0,5*
Any other	*A*	*1*

Work experience advantage

Experience gained in the world of work was identified as an advantage, irrespective of the type of work undertaken.

For each year of work experience	*1*

Tertiary education advantage

No candidates had completed tertiary education but, having embarked on a course of study, whether full or part time was assumed to be an advantage.

For each year of equivalent full-time study	*1*

The advantages which it was assumed would lead to better map reading performance were maturity level, home language, education background and work experience (see figure 5.6). Those factors assumed to influence their ability to read maps were scored, each point representing an assumed advantage. This assessment was carried out for the sole purpose of testing the comparative difficulty of the two tests, and was not based on any known model. Candidates' scores were ranked and alternate ranks were allocated to each group. There was no further use for or reference to this ranking.

5.2.2 Hypothesis, assumptions and data collection

The hypothesis is that the self-instruction programme can improve map reading performance because it provides practice in the skill of map reading. The improvement will be shown by greater accuracy (more correct answers) in less time. The pre- and post-tests will give comparative scores which will show whether there is an improvement in comprehension after following the programme. If the time taken to complete the post-test is less than the time for the pre-test, then this will be a further indication of improved performance. Apart from this evaluation of the partly completed programme, assumptions about the pre- and post-tests, and about the administration and efficacy of the map reading exercises were also tested.

- Test S and Test E are assumed to be of equal difficulty.
- For ease of administration in the classroom it must be possible to complete at least one exercise during an average lesson period. It was assumed that the time required to complete each exercise would initially be 20 - 30 minutes which would be reduced with practice.
- The exercises are of equal difficulty with the level of difficulty increasing from question one to question ten.
- Introductory information about the map area makes the map reading task easier.

Once the pre-tests had been completed, candidates selected an initial work card at random and settled down to answer the questions. Proof-reading report/answer sheets had been designed and the candidates filled one in for each exercise (appendix G). They were asked to indicate their start and finish times and this was carefully checked. They were instructed to draw a minimum of three cards from each suit, in any order, as long as they drew one odd number, one even number and one picture card. If their score on any one of these initial cards was eight correct answers out of ten, they could consider that they had mastered that group of symbols and could then go on to draw cards from another suit. If, after three cards, they had not met the performance criteria, they were to continue drawing cards from the same suit until they had achieved the desired result. This pattern was to continue until they had achieved a minimum of 80% on at least one card in each suit. Five candidates achieved the required score in the minimum of twelve exercises, and each agreed to work through four more exercises to test the value of the introductory texts to each exercise.

Candidates were supplied with graph sheets on which to graph their progress as they checked their answers to each exercise. A record was kept of the order in which the exercises had been completed. They were encouraged to ask for assistance with any problems that they might encounter, whether geographic, cartographic or administrative. The candidates wrote the post-test after they had completed the required number of exercises.

5.2.3 Test S and Test E are assumed to be of equal difficulty

Before claiming improved map reading performance, the difference in the level of difficulty between the pre- and post-tests must be established. The division of the candidates into two equal-ability groups has been explained in 5.2.1. The scores for their pre- and post-tests are listed in figure 5.7.

When used as pre-tests, the mean score out of 25 for Test S was 16.2 while for Test E the mean was 16.0, a difference of only 0.2. When the tests were swapped and given to the candidates as post-tests there was a slightly bigger difference between them (1.6). The mean for Test S was 20.1 and for Test E, 18.5. Although this is a small test group, the small difference between the test averages indicates that the tests are not significantly different.

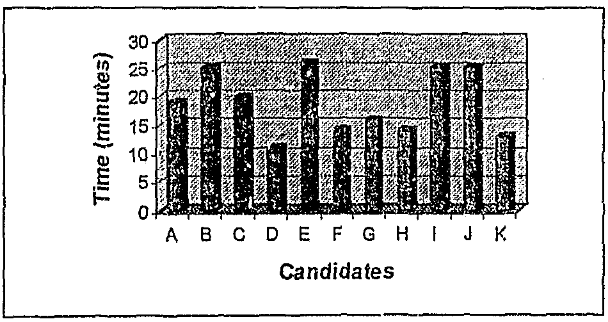
Figure 5.7 Comparing scores for Test S and Test E

Candidate Code	*Pre-test* Test S	*Pre-test* Test E	*Post-test* Test S	*Post-test* Test E
A		12.5	20.0	
B		16.0	18.5	
C	14.0			15.0
D	16.5			18.5
E		11.0	18.5	
F	19.0			23.0
G		20.5	22.0	
H		20.0	21.5	
I	14.5			15.5
J	12.5			17.0
K	20.5			22.0
Total	97.0	80.0	100.5	111.0
Mean	16.2	16.0	20.1	18.5

5.2.4 The time taken per exercise will be reduced with practice

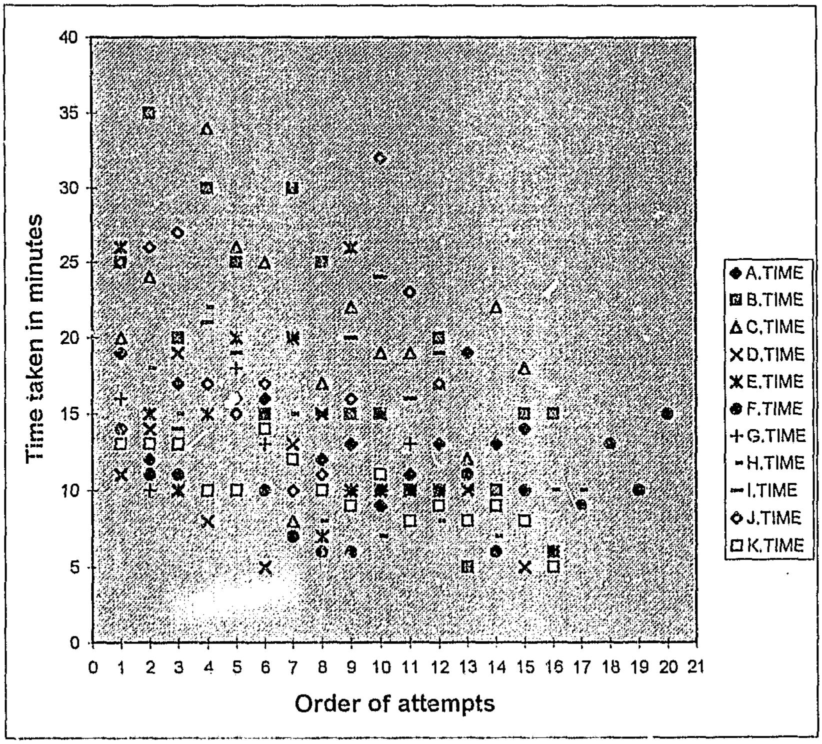
The time taken by each candidate to complete the first exercise is plotted in figure 5.8, which shows that the range was greater than anticipated and candidates did not take as long as anticipated. Only five fell within the expected parameters while the majority took far less time than expected with a minimum of 11 minutes and a maximum of 26 minutes. The average time taken to complete the first exercise was 19 minutes.

Figure 5.8 Time taken to complete first exercise



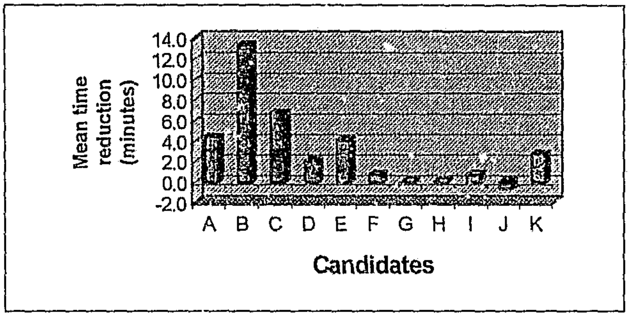
The time taken by each candidate for each exercise was plotted against the order in which it was completed and is presented as a scatter graph (figure 5.9). Although the overall trend is negative, time varied widely around this declining mean. This can be accounted for by differences in individual ability and also indicated that some exercises may be inherently more time consuming than others.

Figure 5.9 General time reduction with practice



Reduction in time taken to complete subsequent exercises was also measured. It was assumed that, due to the unfamiliarity of the task, the first exercise would take longer than any subsequent exercise. To reduce this potential exaggeration, the average time taken for the second, third and fourth exercises was compared with the average time taken for the last three exercises which were completed before meeting the criteria for mastery. The comparison is presented in figure 5.10.

Figure 5.10 Time reduction per candidate



Even with this smoothed data, the predicted time reduction was observed. For most candidates there was a measurable time reduction between the average time taken for the first three exercises and the time taken for the last three exercises completed before meeting the mastery criteria. This is very encouraging because competence is indicated by fluent performance of operations. The maximum time reduction was 13.3 minutes, the mean was 3.1 minutes. Two candidates showed no reduction in time taken and one took 0.7 minutes longer on average to complete the last three exercises.

There was a marked difference in time taken between candidates as well as time taken by individual candidates for each exercise. Time is an important consideration when devising a teaching programme to be used in schools where the time allocation per teaching period, per subject, per day is rigid. Flexibility must therefore be built into the programme. These differences must be accommodated and a classroom strategy devised to ensure that some pupils are not sitting unchallenged in the class while their classmates are busy.

5.2.5 The exercises are of equal difficulty

The raw error scores for each exercise could not be used to compare their difficulty because some exercises were attempted more often than others. As each exercise consists of ten questions, the answer to each one becomes a potential error. To compare the difficulty of the exercises, the actual number of errors was calculated as a percentage of the potential errors (figure 5.11.a, b, c and d). Each exercise was drawn at least twice, one (the ace of spades) was drawn six times but the average number was 3.2. The potential error scores ranged from 3% (Clubs 3) to 42% (Spades 6) with a mean of 18.8%. This marked variation may be explained partly by the fact that exercises were drawn at a wide variety of incidence. Some were drawn as initial exercises and others after repeated practice. The large range of values strongly suggests that the exercises are not of equal difficulty.

Figure 5.11.a Potential error analysis per exercise: **rural settlement (♥)**

CARD	*Question numbers*										*Tot.*	*Errors*		
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*frequency*	*Potential*	*Actual*	*%*
ACE			1		0.5	2		0.5	0.5		3	30	4.5	15%
H2		3		2		2	2.5	2	1	2	4	40	14.5	36%
H3	1	1	1		1		2.5	3	1	1	3	30	11.5	38%
H4	1			1.5	2		1	1		1	2	20	7.5	38%
H5			1	2	1	0.5		1	1		3	30	6.5	22%
H6							1		2	1	2	20	4	20%
H7			1	1		1.5	1			1	3	30	5.5	18%
H8									1		2	20	1	5%
H9		2			1		1	1			3	30	5	17%
H10		1				1	0.5			2	3	30	4.5	15%
JACK		1	1	1	1		1		3.5		5	50	8.5	17%
QUEEN			1		2	1	2		1		4	40	7	18%
KING		0.5	1					1.5	1		3	30	4	13%
Total	2	8.5	7	7.5	8.5	8	13	10	12	8	40	400	84	21%

Figure 5.11.b Potential error analysis per exercise: **transport (♦)**

CARD	*Question numbers*										*Tot.*	*Errors*		
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*frequency*	*Potential*	*Actual*	*%*
ACE				2			3	1	1	1	4	40	8	20%
D2						1			2	1	3	30	4	13%
D3		1	1	3	0.5	2		1	1	1	5	50	10.5	21%
D4				1			1	1		1.5	2	20	4.5	23%
D5							1		1	1	3	30	3	10%
D6				2					1	1	4	40	4	10%
D7									1		2	20	1	5%
D8						2		2			2	20	4	20%
D9			1								2	20	1	5%
D10		1					0.5	2	1	1	3	30	5.5	18%
JACK				1			1		2	1	3	30	5	17%
QUEEN		1			2			2		2	2	20	7	35%
KING				1			1	1	0.5		4	40	3.5	9%
TOTAL	0	3	2	10	2.5	5	7.5	10	11	11	39	390	61	16%

Figure 5.11.c Potential error analysis per exercise: **landscape (♠)**

CARD	*Question numbers*									*Tot.*	*Errors*		
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*frequency*	*Potential*	*Actual*	*%*
ACE	1			3	2	2	6	1.5	4	1	6	60	20.5	34%
S2	1		1	1	1.5	1		2		2.5	5	50	10	20%
S3					1		1.5	2	4	2	4	40	10.5	26%
S4		1	2	2	1	1	2		1		3	30	10	33%
S5		1	0.5	2	1		2	4	2	1.5	5	50	14	28%
S6	0.5	0.5	2	1	1.5	1		2	1	3	3	30	12.5	42%
S7			0.5	1.5		0.5		1			3	30	3.5	12%
S8										2	2	20	2	10%
S9				2				1		2	2	20	5	25%
S10		2			0.5		1	1.5	1		2	20	6	30%
JACK							0.5	1		1	2	20	2.5	13%
QUEEN	0.5				2				1	3	4	40	6.5	16%
KING		1	0.5	3	0.5		3	1			4	40	9	23%
TOTAL	3	5.5	6.5	16	11	5.5	16	17	14	18	45	450	112	25%

Figure 5.11.d Potential error analysis per exercise: **urban settlement (♣)**

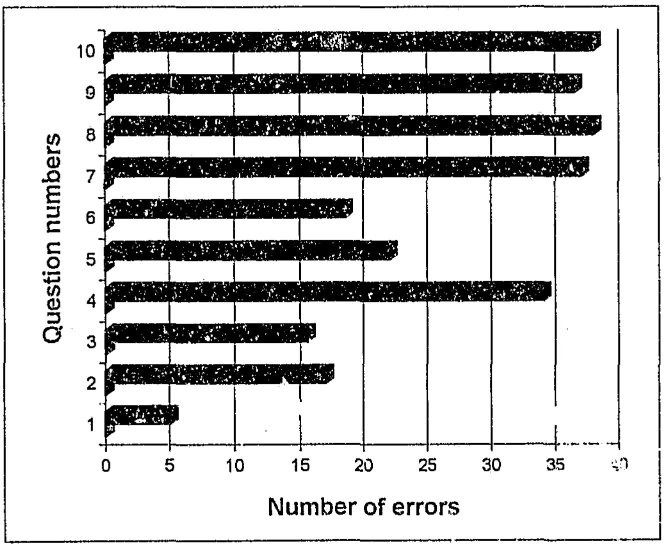
CARD	*Question numbers*									*Tot.*	*Errors*		
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*frequency*	*Potential*	*Actual*	*%*
ACE				2	2	1			2	2	4	40	9	23%
C2	1			2	1	1			0.5		4	40	5.5	14%
C3			0.5	0.5							4	40	1	3%
C4		1		0.5							3	30	1.5	5%
C5				0.5				2			3	30	2.5	8%
C6		1		1	1			1	1	1	3	30	6	20%
C7									2		2	20	2	10%
C8							2			1	2	20	3	15%
C9	1			1			1	1	0.5	1	3	30	5.5	18%
C10				1	1	2		1	1		4	40	6	15%
JACK	0.5				1			2	1	1	2	20	5.5	28%
QUEEN				0.5	2				0.5	0.5	3	30	3.5	12%
KING		0.5				1				1	4	40	2.5	6%
TOTAL	2.5	2.5	0.5	9	8	5	3	7	8.5	7.5	41	410	53.5	13%

Average potential error scores for all exercises in each of the four themes were compared. They ranged in difficulty from Clubs (**urban settlement**) 13%, Diamonds (**transport**) 16% and Hearts (**rural settlement**) 21% to the most difficult, Spades (**landscape**), with a potential error score of 25%. Spades was also the suit which had the highest frequency of work cards used (45) compared to Clubs (41), Hearts (40) and Diamonds (39). This suggests that learners had to draw more cards in this suit to reach the mastery level of eight correct answers out of ten.

5.2.6 Difficulty increases from question one to question ten

Within the range of questions it is assumed that the difficulty factor increases from number one to number ten because the exercises were structured to challenge the learners at an increasingly higher cognitive level (figure 5.4). Taking all the exercises as a whole, the trend supported this hypothesis but, looking at each exercise, there were anomalies in the trend. Number ten and number eight had the highest error score. This is illustrated in figure 5.12 which shows the total error score for each question number on a bar graph. Generally there is an increase in errors with the last four questions tending to be more difficult than the first six. Number four shows a higher error value than expected.

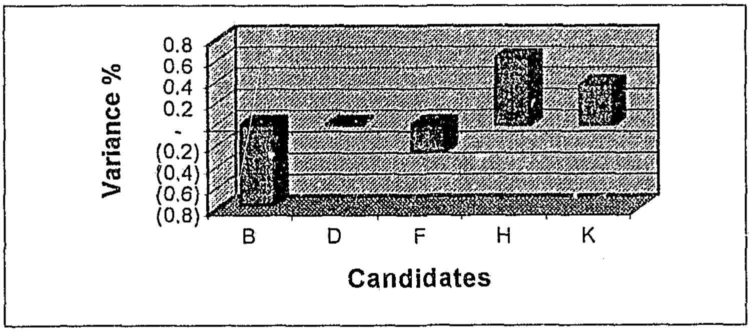
Figure 5.12 Errors per question



5.2.7 A description of the mapped area simplifies the map reading task

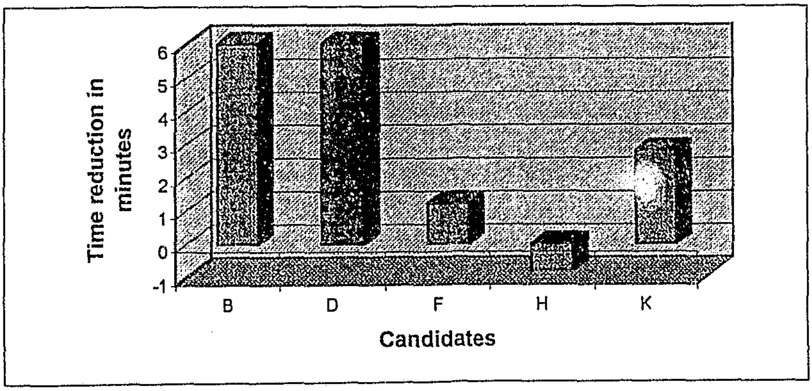
Five out of the eleven candidates needed to complete only the minimum number of three exercises in each section (in order to achieve the required 80% proficiency) to move to the next suit. Those who managed to do the twelve exercises well within the allocated time completed a further four exercises, one from each suit, without the introductory text. The score and time taken for the last four required exercises was averaged and compared with the score and time taken for the extra text-deficient exercises.

Figure 5.13.a Influence of introductory text on score



The differences in the scores for each candidate were plotted in figure 5.13.a. The score for the text-deficient exercises varies, in comparison with the exercises with text, from 6% better to 8% worse. There is no pattern to the variance suggesting that this assumption cannot be verified or rejected. Unfortunately there was no opportunity to test this hypothesis with the slower performers.

Figure 5.13.b Influence of introductory text on time



When comparing the time taken for both groups of exercises (figure 5.13.b), there is a time reduction for the exercises without text, four out of th· · less time with a maximum time saving of six minutes. The reduction in time could indicate that the learners saved time by not having to read the introductory text or that they performed better without having this information. This finding suggests that the introduction is unnecessary and therefore that the assumption is invalid.

The assumption about the introductory text has been tested with a very small group, most of whom showed a relatively high degree of map reading proficiency. Perhaps better map readers have no need of such information, but, as there was no opportunity to test this assumption with less proficient learners, it cannot be rejected. Although it was intended that this aspect of the programme design be tested during the school trial, there proved to be even less time available and the question posed in 5.1.9 therefore remains unanswered - does information about the area shown on the map, make the map reading task easier? It is hoped that at some future date this matter can be investigated further.

5.3 MAPTRIX HAS THE POTENTIAL TO IMPROVE MAP READING

Some of the assumptions about the self-instruction programme and the conditions under which the pilot test was conducted have been outlined. Now it remained to test the main hypothesis which is that, even in its incomplete state, Maptrix can improve map reading performance because it provides practice in the skill of map reading.

To test this hypothesis the pre-test and the post-test were conducted. The pre-test was administered after the participants had been informed of the objectives of the programme. They were supplied with a brief introduction to the origins of the map on the Mowbray Style Chart which had been designed to show all the symbols currently in use on the 1:50 000 topographic map. As already discussed, each test consisted of twenty-five questions based on this map, onto which an alpha-numeric grid had been placed. An answer sheet had been prepared and candidates were instructed to note their start and finish times. There was no time limit imposed.

After the completion of the programme the end test, of equal difficulty, was administered and the results compared. To measure the improvement in skill level two criteria were used: the gain score and the reduction in time. The gain score (figure 5.14) is the difference in the score between the pre-test and post-test expressed as a percentage of the pre-test score. The gain score was positive for all candidates, including those who had performed well in the pre-test. The minimum gain was 6.9%, the mean gain 22.65% and the maximum gain 68.2%.

Figure 5.14 Gain scores

Candidate	Pre-test		Post-test		Gain	
code	/25	%	/25	%	/25	%
A	12.5	50.0	21.5	80.0	7.5	60.0
B	16.0	64.0	18.5	74.0	2.5	15.6
C	14.0	56.0	15.5	60.0	1.0	7.1
D	16.5	66.0	18.5	74.0	2.0	12.1
E	11.0	44.0	18.5	74.0	7.5	68.2
F	19.0	76.0	23.5	92.0	4.0	21.1
G	20.5	82.0	22.5	88.0	1.5	7.3
H	20.0	80.0	21.5	86.0	1.5	7.5
I	14.5	58.0	15.5	62.0	1.0	6.9
J	12.5	50.0	17.0	68.0	4.5	36.0
K	20.5	82.0	22.0	88.0	1.5	7.3
Total	177.0	708.0	214.5	846.0	34.5	249.1
Mean	16.1	64.4	19.5	76.9	3.1	22.6

Figure 5.15 Time reduction

Candidate	*Time in minutes*			
code	Pre-test	Post-test	Difference	% less
A	36	23	13	36.0
B	48	30	18	37.5
C	54	36	18	33.3
D	28	23	5	17.9
E	45	20	25	55.6
F	26	19	7	26.9
G	41	28	13	31.7
H	32	23	9	28.0
I	45	35	10	22.2
J	48	37	11	22.9
K	31	23	8	25.8
Total	434	297	137	337.8
Mean	39.5	27.0	12.5	30.7

The time reduction, illustrated in figure 5.15, is the difference between the time taken for the pre-test and the post-test, expressed as a percentage of the time taken for the pre-test. All candidates showed a time reduction, the minimum was 17.9% or 5 minutes, the mean was 30.71% or 12.5 minutes and the best reduction was 55.6% or 25 minutes.

Improved map reading performance has been shown by higher scores on a map comprehension test and by a reduction in the time taken to complete the test. Both these indicators show that the skill of all participants improved as a result of using the partially completed self-instruction programme.

5.4 DISCUSSION

5.4.1 Review of hypothesis and assumptions

The hypothesis that map reading performance will be improved by the practice offered in the Maptrix self-instruction programme was supported by the evidence of improved scores and reduced time taken to complete the map reading tasks. The time taken to complete the initial exercise was shorter than expected, but the assumed trend of reduced time for subsequent exercises was verified. The assumption that the exercises are of equal difficulty was not supported by the evidence and, although the level of difficulty per question increases from question one to question ten, the rate of increase was not constant. The levels of difficulty were reassessed and adjustments. Although the test population was very small, the evidence supports the assumption that the pre- and post-tests are of equal difficulty. The evidence did not support the assumption that an introductory text describing the mapped area would improve map reading performance.

5.4.2 Proof-reading

The professional cartographic proof-reader found a number of errors in the text of the questions which were rectified concurrently with other adjustments to the programme. Her many valuable comments and suggestions are gratefully acknowledged.

The pupil survey officers spotted errors in the text but their most valuable input was in identifying instructions that were not sufficiently specific. To facilitate proof-reading, the answers were supplied with the exercises. Although the candidates were asked not to turn up the answers until they had completed the exercises, there was no way of monitoring whether the availability of the answers influenced the participants' accuracy. Nevertheless, the questions with the lowest error scores were checked for leading the learners too close to the answers. Questions at both ends of the error scale were checked against the cognitive levels that they were designed to assess. Those exercises with the highest potential error scores were closely scrutinised and the wording improved.

An administrative task which took more time than expected was checking the card selection to ensure that all cards were drawn at least twice (for proof-reading). A number of cards were favoured. Four cards were drawn five times each, including the Jack of Hearts, three of Diamonds and the two and six of Spades. The Ace of Spades was drawn six times. The number eight was very seldom selected. In some suits it was necessary to withdraw all other even numbered cards to force the selection of number eight. On inquiry it was discovered that in a card game very popular in the local area, the eight was an 'unlucky' card. Only eleven learners were using the programme designed for a class of thirty to forty so there was always a wide selection of cards available. It is hoped that the 'favouritism' noticed in the pilot test will not happen in the classroom when more pupils will need more work cards.

5.4.3 Participant response

By using this particular group of participants, the administration of part of the programme could be assessed and proof reading done at the same time. Although the pilot study was carried out within the employment situation, their enthusiasm and willing co-operation were most appreciated. The maturity level of the candidates meant that there were no discipline problems and most instructions were carefully followed.

They were able to give first-hand accounts of the learning situations in under resourced schools. Many of the advantages of the pilot test, came not from the statistical analysis of the data, but from discussions with the candidates who participated in the study. One participant said that she had given up geography at school "because of the maps". She commented further, "If I had had such a system to help me, I would not have done so". When I mentioned that a trial was to be carried out at a school, she expressed concern that "all schools needed this thing, not just one". A copy of an unsolicited letter from one of the other participants is included as an example of the positive encouragement received (appendix I).

Because very few of the pupil survey officers spoke English at home, they highlighted the need for carefully worded, unambiguous instructions. Although some candidates worked through the whole programme, without passing any comment or feeling the need to make inquiries, others engaged in most valuable discussion and made useful suggestions for clarification of the text. Their contributions are gratefully acknowledged and were incorporated into the prototype of the learning programme before the classroom trial.

5.4.4 Administration of the Maptrix pilot test

Conducting the pilot test revealed a number of aspects requiring further refinement of the self-instruction programme before introduction into schools. Monitoring the work flow revealed an unexpected bottleneck in the administration of the programme. Placing all the work cards in one box meant that participants had to wait in a queue to select the next work card. Using a separate box for each suit soon alleviated the problem. The fact that the programme was incomplete highlighted the need for the missing items: the lesson texts, the illustrated symbol explanations and the pupils' answer booklets.

It is only during a classroom trial that the demands on the teacher (or programme supervisor) can be established. During the pilot study much time was taken up explaining geographic terms and concepts. It is expected that once the lesson texts and symbol explanations are available this will not be necessary. Control of the work cards and answer cards will fall on the teacher. This aspect of administering the programme will have to be carefully monitored when running a school trial so that findings can be included in a teacher's guide. The number of learners will be much larger and thus the teacher will be kept busy answering queries. Opportunities for using peer assistance must be identified, giving the teacher time to offer mediation to improve map reading performance.

5.5 FORMATIVE CONSOLIDATION

Having completed the pilot test and received the corrections and comments from the cartographic proof-reader, all exercises were scrutinised once more and the text of both questions and answers was corrected or adjusted to ensure that there would be no errors or misconceptions in the prototype. The order of some questions was changed where they had not been correctly ranked according to their level of difficulty. This process contributed towards the completion of steps nine and ten of the instructional design model of Gagné and Briggs (appendix D).

One aspect of their design recommendations that had received little attention prior to the pilot test was the teacher training referred to in step nine. Although the emphasis of the Maptrix programme is self-instruction, this cannot happen without the careful management of the learning resources and the monitoring of learners' progress. Running the pilot test raised the awareness of what might go wrong in the classroom when much larger numbers of learners would be using the programme. One more component of the Maptrix Kit was thus identified, a teacher's guide. After running the classroom trial, a format for such a guide was designed and is discussed in the last chapter.

CHAPTER 6

MAPTRIX: FROM FORMATIVE EVALUATION TO FINAL ASSESSMENT

6.1 INTRODUCTION

In the last two chapters the design, initial development and pilot testing of the self-instruction programme for topographic map reading have been described. This process produced the items for the fronts of the work cards and answer cards (figures 5.1.a and 5.2). These components constitute the main body of the programme providing for both self-instruction (step 7) and self-assessment (step 8) in the instruction design model of Gagné and Briggs (1974) that was discussed in chapter four. The pilot test made it possible to improve what had been done thus far and also highlighted the need for the scaffolding materials on the back of the work cards: the lesson texts and the illustrated symbol explanations. Individual items for the pupil booklet had been trialled (the graphs and answer sheets) but the verbal instructions for following the programme still had to be converted to text and the layout of the booklet had to be designed.

The first part of this chapter relates how all the items for each component were completed and assembled to produce the first prototype of the Maptrix Kit. It then takes Maptrix into a classroom for trialling where the main hypothesis and some of the assumptions tested in the pilot study are tested again for validity with a larger and more diverse sample of learners (Smith, 1985). The results of the classroom trial are then covered in this final chapter as well as the recommendations arising out of this trial. Steps ten and eleven of the design model of Gagné and Briggs (1974) are thus taken, and recommendations for taking step twelve are made (appendix D).

6.2 DEVELOPMENT AND LAYOUT OF THE LAST COMPONENTS

When working through the self-instruction programme, the main task of learners is to use the front of the work card to read the map and answer the questions. The back of the work card provides guidance which they may need extensively when they start the programme but which, it is hoped, learners will use less and less as their skills improve.

6.2.1 Illustrated symbol explanations

Because map reading research stressed the importance of a well developed geographic concept base for map comprehension, the illustration and explanation of each descriptive word and symbol was done with particular care. It is acknowledged that using a topographic map to study the local environment is an excellent means of learning map reading but, investigating the teaching of map work in South African schools revealed that few learners have the opportunity to use their local topographic map sheet in the field. Even for those who do have this opportunity, it is unlikely that they will do field work in a variety of landscapes using local maps. Some vicarious substitute has to be offered for such fieldwork.

Illustrations were needed for the features represented on topographic maps either by symbols or descriptive words. Earlier attempts to have these illustrations sketched proved unsatisfactory. Teaching materials for adult, Map Awareness and Map Literacy workshops were being developed at the Chief Directorate of Surveys and Mapping concurrently with the development of the final components of Maptrix. Slide photography, commissioned to capture images of the full range of natural and constructed features, represented by symbols and descriptive words on the 1:50 000 topographic map, was thus made available. The high standard of this photography has contributed significantly to the quality of the support material. Figures 6.1 to 6.4 that follow, are examples of completed symbol illustrations used in the Maptrix prototype.

Although some features would be familiar to most learners, such as a school or a church (figure 6.1), there are features which are unknown to learners from different parts of South Africa. The coastline (figure 6.2) is a difficult concept to grasp for inland inhabitants who have never seen the sea. A freeway (figure 6.3) is difficult to visualise for a young learner living in a subsistence farming area far from major transport routes, while the term *other road* (figure 6.4) is rather vague to most map users.

Figure 6.1 Illustrated symbol explanation for a place of worship

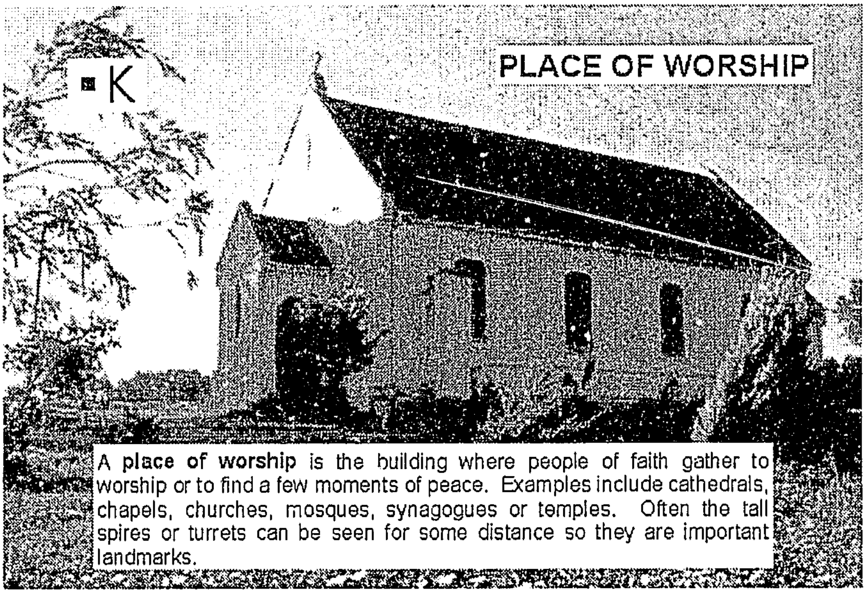


Figure 6.2 Illustrated symbol explanation for the coastline

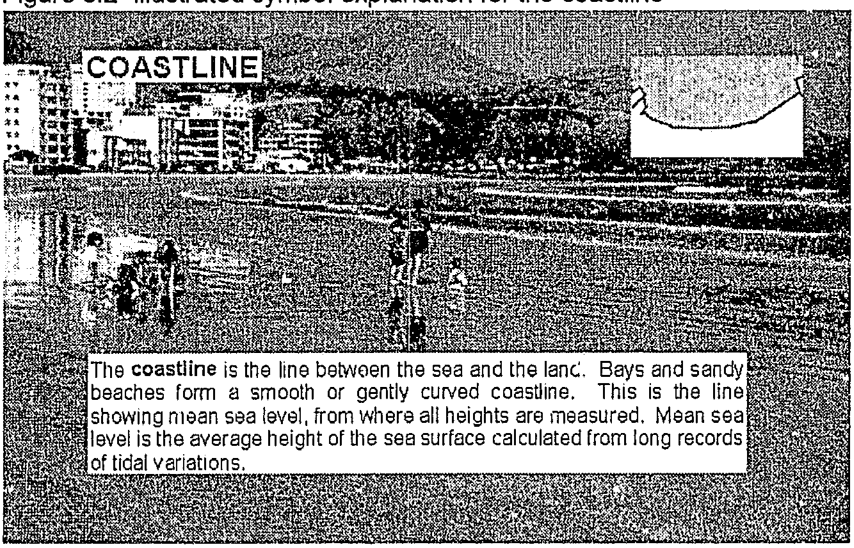


Figure 6.3 Illustrated symbol explanation for a national freeway

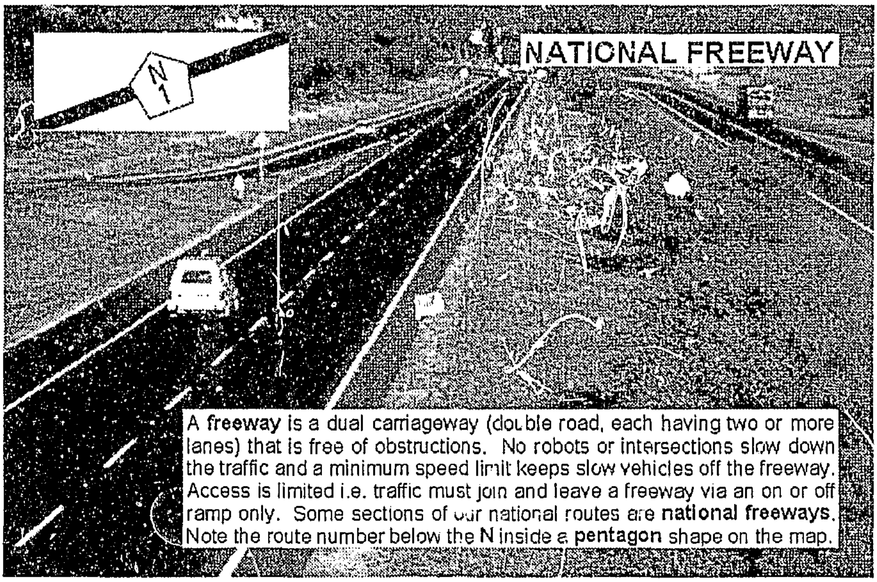
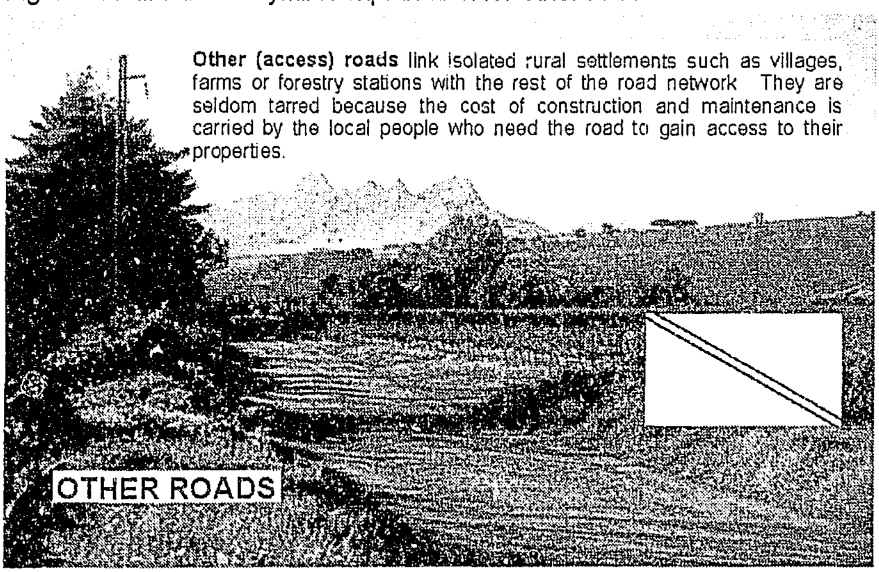


Figure 6.4 Illustrated symbol explanation for other roads



The text for each explanation is prepared using a standardised format. The name of the feature or structure is printed in bold type, then its appearance is described and this is followed by its use and/or importance. The facts presented in these explanations have been checked by senior cartographers and land surveyors and corrected where necessary.

Adobe Photoshop was used to produce each composite illustration from three ingredients: slides, explanations and enlarged symbols. The slides were scanned on a vexel scanner at a high resolution and converted to a tif format. The text for each illustration was manipulated to fit into a box of predetermined size and converted to a bit map. The symbol images, generated for digital map production, were enlarged and imported into the image. Each of the 88 completed illustrations were then stored as tif files.

6.2.2 Lesson texts

Providing lessons was not initially part of the envisaged programme. Reports on learning research, however, stressed the importance of helping learners develop a framework into which concepts can be linked. A lesson text was prepared for each of the four themes to create such a concept framework. The main purpose of the lessons is to explain related terminology while providing a geographic frame of reference for the map reading tasks. The lesson should assist learners to link concepts represented by individual symbols into a larger, spatial concept framework.

Time spent reading text reduces the time for active learning. A careful balance is needed between giving too much and too little information. Lesson texts were thus kept short and interesting by breaking down the original four lessons, one for each theme, into twelve different lesson texts, each focusing only on the symbols represented in a sub-theme (appendix E). Although a lesson is available on the back of each work card, learners are not instructed to read it before starting work on an exercise. It is suggested, rather, that reading the lesson might be helpful if a low score is gained for the initial exercise on a sub-theme. Each lesson starts with a definition of the main theme and then the sub-theme, followed by the learning objective for the work card. The main body of the lesson explains, in a few brief paragraphs, the terminology and associated concepts covered in the lesson topic.

6.2.3 The pupil booklet

The proof reading report sheets and loose graphs used in the pilot study were combined into a booklet for use in the classroom so that

- answer sheets for all exercises could be kept together,
- instructions are available to refer back to, after the teacher has given them verbally,
- learners' answers are available to teachers who can diagnose problem areas and offer mediation,
- progress graphs, correctly filled in, indicate where the learner is in the programme,
- by charting their own progress learners will be motivated by their achievements.

The booklet contains the instructions for following the programme, answer sheets for 24 exercises and the progress chart (figure 5.1.c). The verbal instructions given during the pilot test are listed as sixteen steps on the front cover (appendix F). The progress chart inside the back cover consists of four sets of bar graphs, one for each theme. Space is available for answering six work cards per theme. The minimum number of work cards to be completed per suit is three, for which learners must attain a score of eight correct answers out of ten to move on the next suit. If learners complete six exercises in the same suit without attaining the 80% level of accuracy, it is recommended that the teacher should investigate the problem and mediate if possible.

The 16-page A5 booklet is small enough to allow learners to conveniently use it alongside the A3 work card on a school desk (figure 6.5). The simple one-colour design can be supplied as a master for photocopying and collating by the teacher.

Figure 6.5 The work card and pupil booklet in use

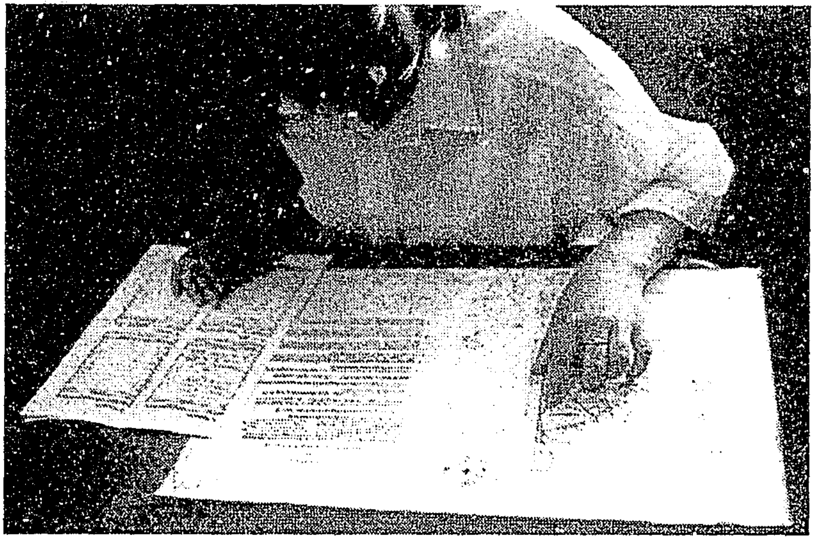
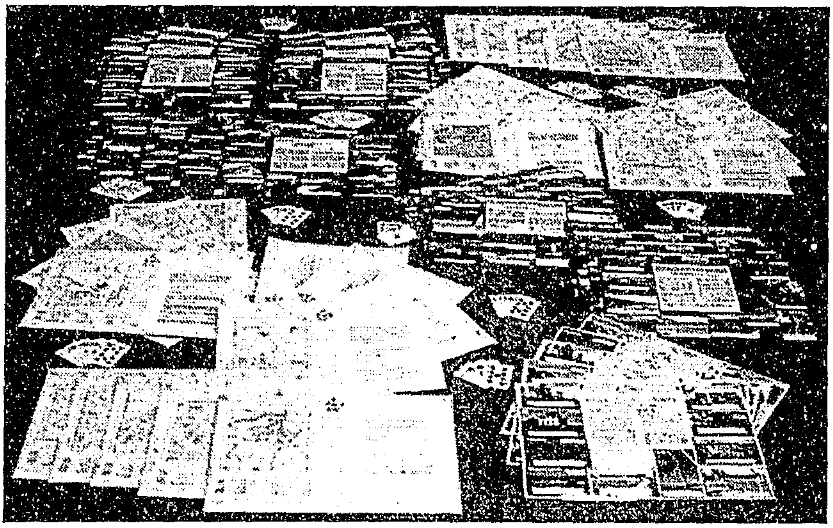


Figure 6.6 The 52 work cards and answer cards of the prototype Maptrix Kit



6.2.4 Assembling the prototype

The grid-referenced map extracts and the exercises, which had been revised and improved after the pilot test, were stuck onto a map background to produce the fronts of the work cards (appendices C.1 and C.2). A Carto character (figure 5.5) displaying the relative playing card suit and number was added.

Adobe Photoshop, designed to enhance and manipulate photographic images, was used to do the layout of the back of each work card. The combination of illustrated symbol explanations on each work card had been determined when writing the questions for each exercise (discussed in 5.1.8). The composite symbol images were laid out on a different colour canvas (background) for all the work cards in each sub-group as shown in figures 5.1.b and 6.6. This was done to help learners identify which themes they had mastered or still had to attempt. When the digital image for each work card, consisting of the ten symbol explanations and space for the lesson text, was reduced to fit onto an A3 sheet, the explanatory text broke up and became illegible (appendix C.3). The limitation of this software package for desk-top publishing and the short time available before the classroom trial meant that the prototype had to be slightly modified. The work cards could not be reduced to less than 50 cm x 35 cm, thus were slightly larger than anticipated.

The fronts and backs of the work cards were glued together. The answers to each exercise were printed and stuck onto the back of the playing card which matched the Carto on the work card. Each work card and answer card in the kit was then laminated. The 52 work cards and answer cards were finished (figure 6.6). During the pilot test, queues formed while candidates waited to select their next work card. To reduce this delay in the classroom, four cardboard trays were made, one for each suit. These could be spread out giving learners four access points rather than one. They were made to fit into each other for easier storage and transport. With work cards and answer cards suitably packed, pupil booklets copied and collated, Maptrix was ready for a classroom trial.

6.3 THE CLASSROOM TRIAL

It is acknowledged that one classroom trial is not sufficient to prove that a learning programme works for all learners in all situations. On the other hand, to assume that this method is effective without a trial would be presumptuous. The focus of this research is the development of a self-instruction method for learning to read the South African 1:50 000 topographic map. The method has taken the form of the prototype Maptrix Kit. After the prototype of the intervention instrument has been assessed and the results analysed in this research exercise, the next step must be the further development and more rigorous testing of the method, with a larger and more diverse sample population. But this falls outside the scope of the present project.

There are two reasons for running a classroom trial. One reason is to assess whether the performance of learners can be modified. The other is to test the intervention instrument itself. In each case there are a number of assumptions made which need to be validated. It was decided to trial Maptrix at a school that was close-by, had a diverse pupil population, and which offered geography to matric (grade twelve). Anyone who needs to learn to read the 1:50 000 topographic map of South Africa may benefit from the programme. But the main target group, for whom the programme was designed, comprises grade ten pupils, just starting the three-year further education and training (FET) phase of geography education. Because it was already close to the end of the school year, it was felt that the year group most suitable to trial the materials would be those in grade nine, ready to enter grade ten in January the following year. The head of the geography department at the third local school that I approached agreed to allow the trial to take place in her department. Her assistance, advice and encouragement are gratefully acknowledged.

6.3.1 The school

Cape Town High School is situated close to the central business district of South Africa's mother city. It dates back to before 1921 (when the Capetonian, the school magazine, was first published) and has a long record of progressive education. The school challenged the apartheid restrictions by admitting pupils of all race groups long before the elections of 1994 heralded changes throughout the education institutions of this country. The school has facilities for approximately 700 pupils who come to the school in grade (year) eight of their school career and are encouraged to complete grade twelve or matric. The pupils are drawn from a wide and diverse feeder area, which includes the medium density inner city residential areas, lower density suburbs and high-density informal housing settlements near the city limits.

Pass rates have been favourable for many years; despite a slight lowering of the standard of matriculation results as the school community has become more diverse in recent years (pers comm, L. Phillips). The pupils are now drawn from various primary schools, previously administered by different education authorities, not enjoying equal resource allocation. Apart from the wider range of ability of the pupils who enter the school, another aspect of this diversity, which may have had an impact on results, is the variety of home languages of learners. The language of instruction at the school is English.

The facilities and staff training are of a higher standard than would be found at most schools in rural areas. Geography is offered to all pupils in grades eight and nine and is then elected by a large percentage each year as one of the six subjects taken from grade ten to matric (grade twelve). Under the geography curriculum still in place at the end of 1997, topographic map studies may be introduced in grade eight and this had been done at Cape Town High. There were approximately 90 pupils in grade nine, divided according to subject selection, into four class groups. It was agreed that the classes at the two extremes of the performance scale would trial Maptrix.

6.3.2 Test group

During the period of the trial a number of pupils were absent for either the pre- or post-test and some were absent for more than half the eight lessons. The data collected from these pupils were not used in the analysis. As a result the sample population consisted of 37 pupils in the higher ability class and 26 pupils in the lower ability class. The pupils completed personal profile questionnaires, the details of the two groups were combined, tabulated and analysed (appendix J). The average age of the test population was 15.5 years ranging from 13.75 to 17 years. This age range in the same grade has two causes. One arises from the practice of passing or failing pupils, from one grade to the next, depending on their score in norm referenced examinations administered by each school. Those who fail to meet a standard of achievement set by the school, repeat the year in the same grade. Although it is preferred that learners attain the age of six years during the year in which they start school, some start when they are either younger or older.

There were 28 males and 35 females in the group. The language breakdown showed that 32% spoke only English at home, 43% spoke English and Afrikaans, 16% spoke English and Xhosa and 6% spoke only Xhosa at home. A further 3% spoke English and another European language at home.

6.3.3 Conducting the classroom trial of Maptrix

The trial was conducted over three weeks during November 1997. The first two weeks and the last week of the month were used. The trial finished one week before the final examinations were written. During the three weeks of the trial each class had eight geography lessons of 35 to 40 minutes each.

During the first lesson, the class was introduced to Maptrix (appendix H4) and briefed on the use of an alphanumeric grid. Pupils then wrote a pre-test. During the second lesson, the playing card deck was described including the names by which the suits are known, as well as the thirteen members of each suit. Some time was spent explaining how the suits were used to identify the four conceptual themes used to divide the programme. The use of the different card numbers to identify the sub-themes was also explained (figure 5.3). The importance of selecting one odd number, one even number and one picture card was stressed to ensure that pupils would encounter the wide range of symbols needed to read a topographic map with comprehension. The use of the bar graph to chart their progress was explained and demonstrated.

Using the answer cards like a deck of playing cards, the pupils were offered the choice of any card as a starting point. These were exchanged for a work card and the class settled down to attempt the first exercise (figure 6.7). Having completed the first work card, they came up to replace the work card and collect an answer card (figure 6.8). They checked their answers against those on the answer card, marking them right or wrong (figure 6.9). After adding up their score, they completed the relevant bar graph on their progress chart (figure 6.10). They then replaced the answer card and selected the next work card, depending on their score and the instructions on the front of the pupil booklet. If an explanation was necessary in order to answer a question, they could consult the information on the back of the work card (figure 6.11). When this was not sufficient to meet their needs, the teacher was available to offer assistance (figure 6.12).

Figure 6.7 Pupils working on the map reading exercises

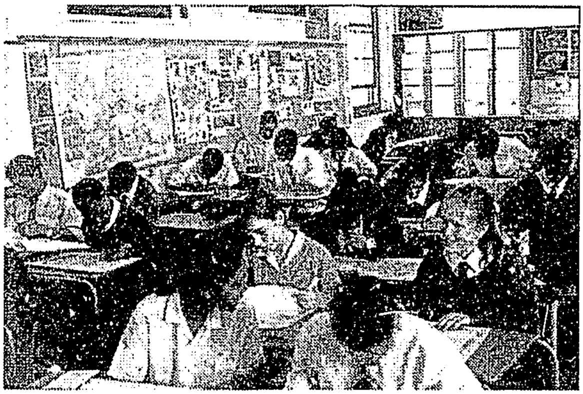


Figure 6.8 Replacing work cards and collecting answer cards

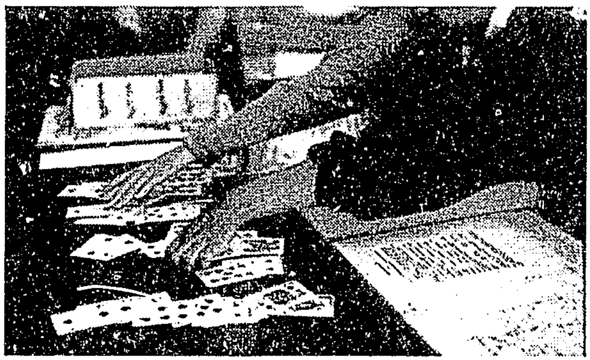
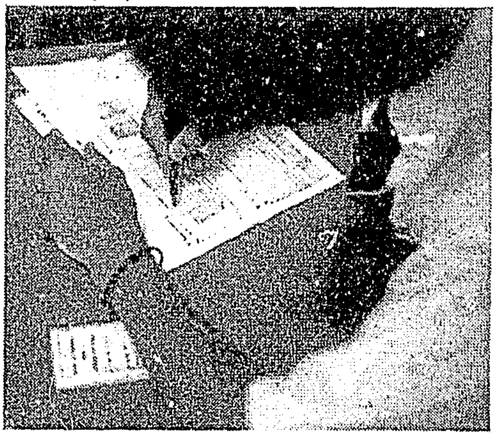


Figure 6.9 Checking and scoring answers

Figure 6.10 Recording progress on the bar graph



⇧ Figure 6.11 Using the information on the back of the work card

Figure 6.12 Getting help from the teacher

Having started the programme in the second of the eight available lessons, the pupils continued selecting work cards and doing the exercises during the next five lesson periods. Pupil booklets were collected at the end of each lesson so that the selection of work cards and progress records could be checked. The class teacher helped hand out the booklets at each lesson and monitored the selection of work cards. When learners required assistance, we were both available to answer their questions. The number of periods available proved to be insufficient for all pupils to complete the minimum number of twelve exercises. Each pupil filled in a personal profile questionnaire (figure 6.13), before completing a post-test in the eighth lesson.

Figure 6.13 Pupil profile questionnaire

My date of birth is __________ (day) __________ (month) __________ (year).
I am male ___ / female ___ (Please ✓)
We speak one ___ / two ___ / more than two ___ languages at home (Please ✓)
Please tick or write down the language(s) spoken at home,

English ___ Afrikaans ___ Xhosa ___ __________ __________ __________

6.4 DATA COLLECTION

Test S and Test E, designed for the pilot test (appendices H.2 and H.3), were slightly modified and used again with this test group (appendices H.5 and H.6). The wording of some questions was changed following ambiguities identified during the pilot test. The grid-referenced test maps (appendix H.1) were handed to each pupil. Test S and Test E were piled alternately and then handed to candidates as pre-tests. They entered their names and indicated the S or E on the answer sheet which accompanied their test (appendix H.7). It was thus possible to ensure that the alternate test could be administered as a post-test. When assessing the pre- and post-tests it was discovered that the answer to question two on both tests was obscured by colour distortion resulting from the colour photocopying of the test map (appendix H.1). This answer was ignored on both tests, hence the results are listed out of 24 and not out of 25 in figure 6.14 (a and b) which compares the scores for Test S and Test E as both pre- and post-tests.

The names of the pupils in each class were arranged alphabetically and substituted with numbers. The numbers 1 to 37 were given to the larger class and numbers 38 to 63 were given to the smaller class (appendix J). The pupil profile questionnaire (figure 6.13), printed on the back of the post-test answer sheet, provided the data about gender, home language and age. The pre- and post-test data and the gain scores have all been listed in appendix J with the information gathered about the test population. Appendix K lists the actual and estimated time taken for the pre- and post-tests. In appendix L the pupils' scores for each exercise are listed from the pupil booklets and in appendix M the same source is used for the details of the question analysis of a sample of twelve exercises.

6.5 TESTING THE HYPOTHESIS

The hypothesis is that Maptrix can improve map reading performance because it provides practice in the skill of map reading. This statement can be expanded to reveal that three linked hypotheses are being tested in this research exercise namely,

- that the map reading performance of learners can be modified,
- that an intervention instrument, based on a self-instruction method, can be developed to improve map reading, and
- that the improvement in map reading performance can be measured.

There are a number of assumptions about the learners, about Maptrix (the intervention instrument) and about the measurement device that was used, which must be validated before the hypothesis can be accepted or rejected. Assumptions about the learners include the influence of age, sex and home language on the modifiability of their map reading performance. Some assumptions about the design of Maptrix were tested in the pilot study and will be investigated again here including the increased difficulty from questions one to ten in each exercise and the equal difficulty of exercises and themes. Further, the assumption that repeated practice led to the greatest improvement will also be examined.

The pilot test revealed no significant difference between the difficulty of Test S and Test E. This assumption must be validated with a larger test population before the results of the pre- and post-tests are used to measure whether Maptrix improved map reading performance. It must be stressed that the sample population is small and that results found here cannot be generalised without further investigation.

6.5.1 Test S and Test E are assumed to be of equal difficulty

To test this assumption, two groups of learners answered the tests alternately as pre- and post- tests. Unlike the pilot test where the two groups had to be 'engineered' (see the last paragraph of 5.2.1), the two groups for the classroom trial emerged by random selection from the method used to hand out the test papers described in 6.4. In figure 6.14.a the results are listed and summarised for those who did Test S and Test E as pre-tests. Figure 6.14.b tabulates the results of Test S and Test E as post-tests.

Figure 6.14.a Pre-test scores for Test S and Test E

Pre-test									
Pupil code	S		E		Pupil code	S		E	
	/24	%	/24	%		/24	%	/24	%
1			13	55	38			9	38
2	12	50			39			12	50
3	17	71			40			10	42
4	10	42			41			8	34
5	8	34			42	4.5	19		
6			9	39	43	9	39		
7	9	39			44	10.5	44		
8			18	76	45			12	50
9			9	39	46			7.5	32
10			3	13	47			5.5	23
11			14.5	61	48	5	21		
12	8	34			49			5	21
13	11.5	48			50			8	34
14	6.5	27			51			10	42
15	13	55			52	4	17		
16	14	59			53	13	55		
17			11	46	54	19.5	82		
18			10.5	44	55	8.5	36		
19			7.5	32	56			6.5	27
20	13	55			57	2	8		
21			14.5	61	58			10.5	44
22	11	46			59	5	21		
23	17	71			60			10.5	44
24			16	67	61			5	21
25			11.5	48	62	5	21		
26			15.5	65	63	3.5	15		
27			9	39					
28	18	76			Mean		42.5		44.3
29	10	42			Std.Dev		19.5		15.3
30	16	67							
31			10	42					
32	14.5	61							
33			16	67					
34			14	59					
35			15	63					
36	9.5	40							
37	5.5	23							

Figure 6.14.b Post-test scores for Test S and Test E

Post-test									
Pupil code	S		E		Pupil code	S		E	
	/24	%	/24	%		/24	%	/24	%
1	20	80			38	16.5	69		
2			22	92	39	16	67		
3			18.5	78	40	16	63		
4			20.5	86	41	16.5	69		
5			20	84	42			12.5	53
6	17	71			43			11	46
7			17.5	74	44			17	71
8	20	84			45	13	55		
9	18	76			46	13	55		
10	16.5	69			47	20.5	86		
11	23	97			48			12	50
12			17.5	74	49	10	42		
13			17	71	50	12.5	53		
14			12.5	53	51	16	67		
15			18	76	52			12	50
16			21.5	90	53			19.5	82
17	20	84			54			20.5	86
18	18.5	78			55			13	55
19	8	34			56	6	25		
20			19	80	57			7	29
21	23	97			58	18	76		
22			15	63	59			18.5	78
23			19.5	82	60	15	63		
24	16	67			61	20	84		
25	17	71			62			11	46
26	19.5	82			63			11.5	48
27	17	71							
28			23	97	Mean		70.1		69.5
29			16.5	69	Std.Dev		16.1		16.3
30			17.5	74					
31	19	80							
32			18.5	78					
33	16	67							
34	18	76							
35	20	84							
36			16.5	69					
37			17	71					

The mean pre-test score for Test S was 42.5% with a standard deviation of 19.5% while the pre-test score on Test E was 44.3% with a standard deviation of 15.3%. This gives a mean pre-test score difference of 1.8% with a difference of 4.2% in the deviation from the mean. The mean post-test score for Test S was 70.1% with a standard deviation of 16.1% while the post-test score on Test E was 69.5% with a standard deviation of 16.3%. This gives a mean post-test score difference of 0.6% with a difference of 0.2% in the deviation from the mean.

Subtraction reveals that the mean improvement for those who did Test S as a pre-test and Test E as a post-test was 27.0%. Those who answered Test E as their pre-test and Test S as their post-test show an improvement of 25.8%. The difference in improvement between the two sets of tests is 1.2%. The mean improvement in scores of the test population is 26.4%. On the basis of the minor differences in scores using the two tests, they have been accepted as being of equal difficulty and the distinction between the test groups falls away in the rest of the data analysis.

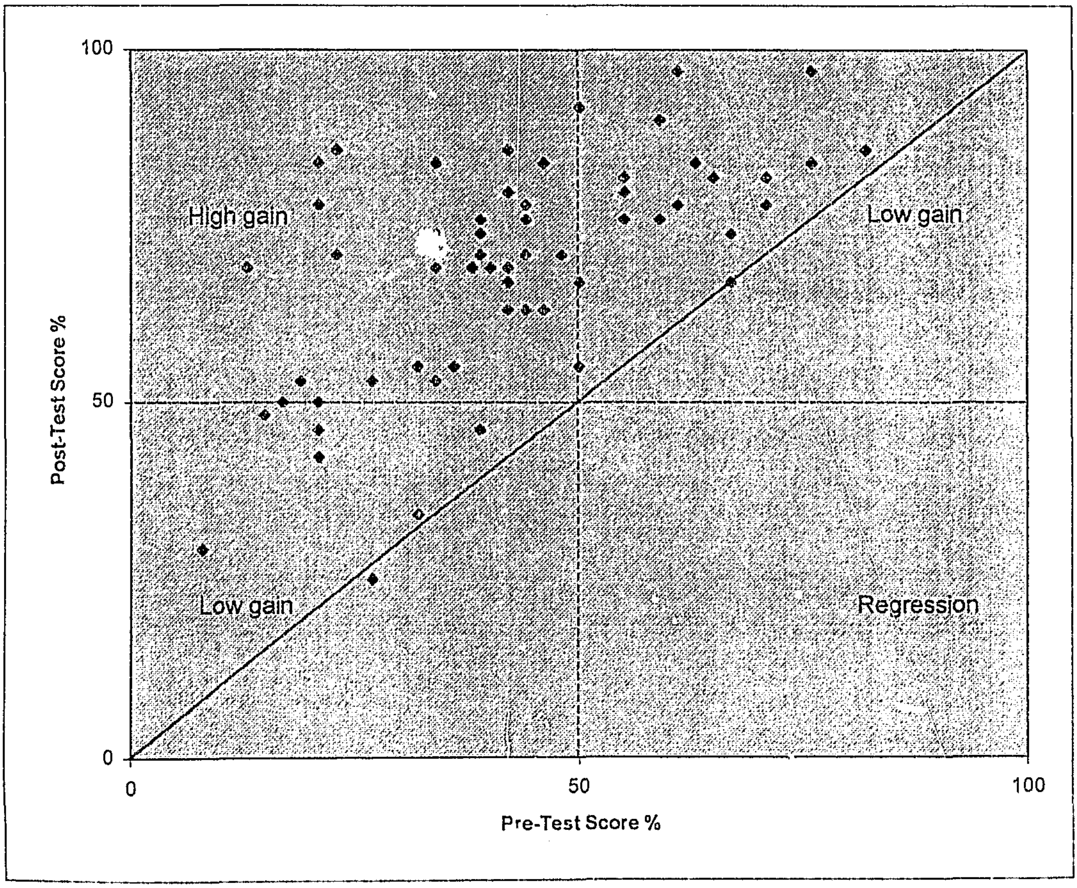
6.5.2 A self-instruction programme can be designed to improve map reading performance

As with the pilot test, improved map reading performance is measured against two criteria, increased scores and decreased time. In 6.5.1 above, the improvement in scores between the pre- and post-tests has already been mentioned. The mean improvement was 26,4%. The difference between the pre- and post-test scores of each pupil is listed in appendix J. Two pupils (numbers 24 and 33) showed no improvement and one (number 56), fared worse on the post-test. Sixty pupils improved their scores, two pupils (numbers 47 and 61) improving by 63%.

Improved performance can be converted to a gain score by expressing the difference between the scores as a percentage of the pre-test score (appendix J). A closer examination of this data showed that of the sixty pupils whose performance had improved, 16 improved by more than 101%, 24 improved by between 51% and 100%

and 20 improved by between 1 and 50%. By plotting the pre- and post-test scores against each other, a gains analysis is illustrated in figure 6.15. Two groups of pupils have low gain scores. The smaller group includes those who achieved low pre- and low post-test scores, showing little improvement in map reading performance even with intervention. The other group with low gain scores includes pupils who had done well in the pre-test and therefore had little room for improvement. In the classroom situation these are the pupils who could help tutor their peers. The third group had high gain scores showing varying degrees of improved performance.

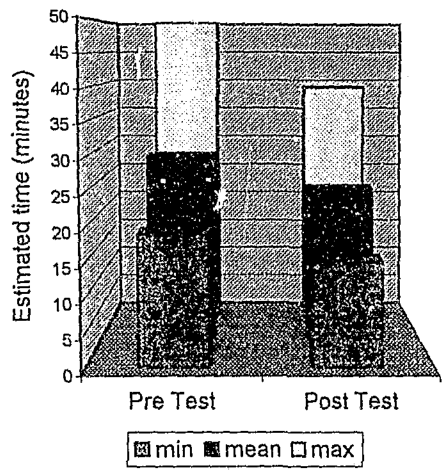
Figure 6.15 Gain score analysis



During the pilot test there was no time limit for the pre- and post-tests. All the participants started together and, as most wore watches, they could easily record their finishing times. In the classroom situation however, the day is divided into fixed lesson periods and many pupils did not have time to attempt all the answers required for the pre-test. Some, although fewer in number, did not complete the post-test either. Further complications were introduced because many pupils did not have their own watches and disturbed others by asking for the time. There was no clock in the classroom and the school bell, which signalled the change of classes, was operated manually and was not punctual. Because the bell times varied, one class was allowed more time than the other.

In order to estimate the reduction in time taken between pre- and post-tests, a time value was required. The rate at which answers were attempted was used to estimate a time value for the completion of the tests (appendix K). Figure 6.16 compares the minimum, mean and maximum estimated time taken to complete the 24 answers for the pre-test and the post-test. Most learners (61 out of 63) attempted the 24 questions in the time available for the post-test, many finishing long before the time was up. When they did the pre-test, only 27 pupils had finished in the time available. The average estimated time required to finish the pre-test was 28.7 minutes with a maximum of 50 minutes and a minimum of 19 minutes. When answering the post-test, pupils took an average of 23.5 minutes (of which only 2 had to be estimated) with the fastest time being 15 minutes and the slowest estimated as 39 minutes. There was a mean time reduction of 5.1 minutes despite the fact that not all candidates had finished the minimum number of cards required to complete the programme.

Figure 6.16 Reduction in time between pre- and post-tests



Using the criteria of both score and time, it has been shown that map-reading performance can measurably be improved by offering learners the opportunity to practice this skill. This supports Feuerstein's (1908) assertion that learners are modifiable and also suggests that map reading may not be as difficult as is generally reported if appropriate teaching strategies are adopted.

6.5.3 *The language factor and self-instruction*

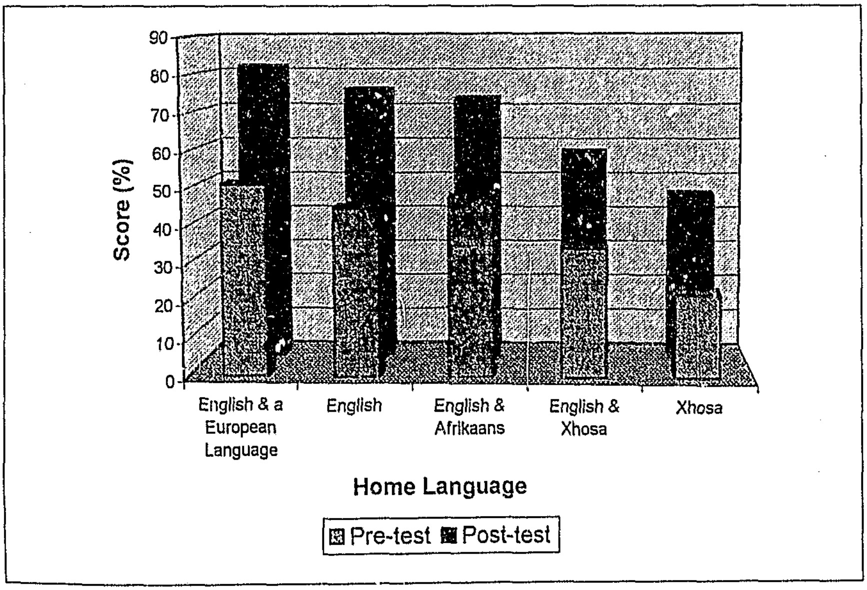
The self-instruction programme was developed in English; the learners who tested the prototype speak a variety of languages at home (appendix J). It is assumed that learners for whom the language of the self-instruction programme is the same as their home language would perform better than those for whom the language of instruction is a second or third language. It is further assumed that if English is the sole home language performance will be better than if it is one of two or more languages.

The graph in figure 6.17 illustrates that all language groups showed an improvement in their post-test scores. The twenty pupils who speak only English at home show the greatest improvement, 28.8%. The two pupils who speak English and another

European language at home who improved by 28.5% followed this group. The largest group of 27 who speak both English and Afrikaans at home scored well on the pre-test and the post-test showing an improvement of 26.5%. The ten pupils speaking English and Xhosa showed an improvement of 23.2% but pre- and post-test scores were both low. The four pupils who speak only Xhosa at home had the lowest test scores but improved slightly more than their classmates (23.5%) who speak both Xhosa and English at home.

Although the group which speaks only English at home showed the greatest improvement after following the self-instruction programme, the difference in the test scores between this group and the others was minimal. Pupils who fared worst speak no English at home. It must be borne in mind that this is a small sample of learners and that the programme should be tested with larger, more homogeneous groups before these assumptions can be confirmed.

Figure 6.17 Test scores for different language groups

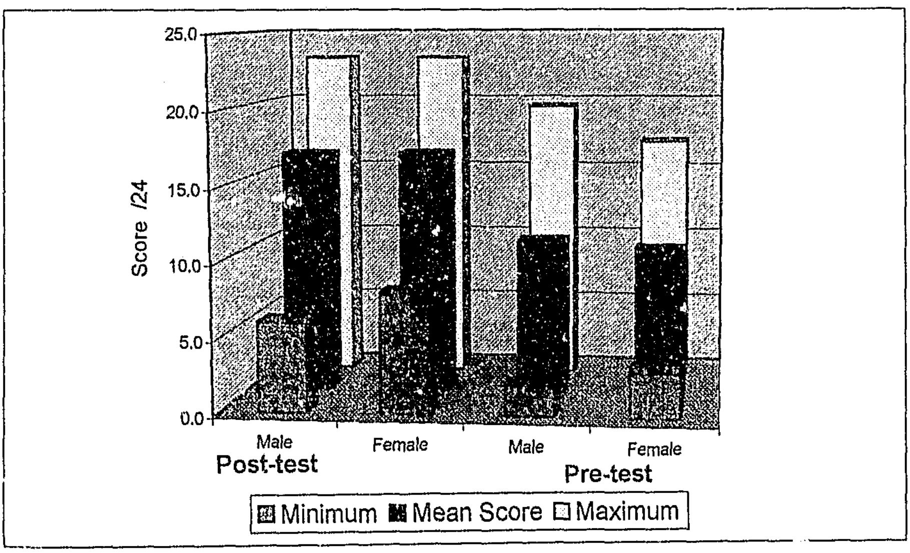


6.5.4 No significant difference in map reading ability between male and female pupils

Although some researchers have found differences in the ability of boys and girls to do map work, it is proposed that this difference is not evident at the skill level required to read maps.

There were 28 males and 35 females in the test population (appendix J). Figure 6.18 illustrates the analysis of their pre- and post-test scores. In the pre-test the males scored a mean of 10.6 and the females 9.9 with deviations around the means of 4.6 and 3.9. The difference in their mean scores was thus 0.7 with the males obtaining the slightly better score. In the post-test, the male pupils' mean score was 16.6 and the females obtained a slightly lower mean score of 16.3. The mean minimum score obtained by the female pupils was higher for both tests. This evidence supports the assumption that there is no significant difference in the ability of the boys and girls, in this test sample, to read maps. The sample was too small to generalise but does point to a need for further investigation.

Figure 6.18 Comparing the map reading ability of male and female pupils

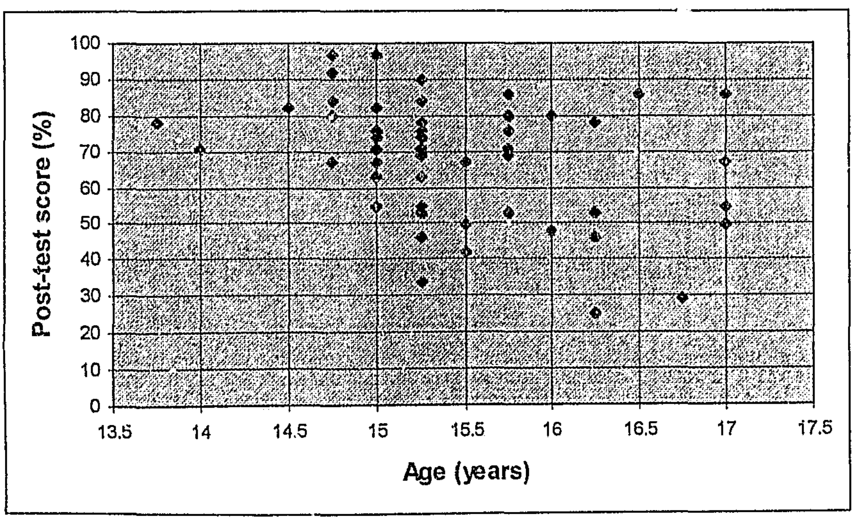


6.5.5 No link between map reading ability and age

Piaget contended that learning ability was influenced by age, which he linked to the stage at which learners attained formal operational thinking. Many researchers have subsequently shown that the attainment of formal operational thinking is not necessarily linked to age but can generally be shown to reflect a stage of cognitive development following on from concrete operational thought (see 2.1.2). It is intended to show that if competence in map reading shows the attainment of formal operational thinking, that this is not linked to the age of the learner. This is especially so in a diverse cultural group where other factors must be sought to explain differences. Such an investigation falls outside the scope of the present research.

In figure 6.19 the age of each pupil has been graphed against their post-test score. The age of the pupils ranges from 13.75 years to 17 years. Up to the age of fifteen years they all scored above 50%, with the maximum scores attained in this age group. From the age of 15.25 years the distribution of scores varies widely with no clear trend indicated. Although the younger pupils performed marginally better than their elders, there does not appear to be a correlation between age and map reading performance in this sample.

Figure 6.19 Comparing map reading ability and age



6.5.6 Repeated map reading practice leads to the greatest improvement

The degree to which practising map reading leads to improved performance is tested in two different ways. The number of exercises attempted by each pupil is compared with both their post-test scores and with the average score which they achieved for all the exercises they attempted.

Greater improvement should be indicated by completion the whole programme. To do so, each pupil must attempt a minimum of twelve work cards; three work cards (with a score of 80% for at least one of them) from each of the four suits. The progress graphs in the pupils' booklets were used to count the number of exercises that they had completed. Some learners needed to draw more work cards from some suits before they attained the prerequisite level of performance. Because the trial was held within a limited time frame, not all pupils had completed the minimum number of work cards while others completed more than was required. The number of work cards attempted by each one is compared to their scores for the post-test and presented as a scatter graph in figure 6.20. A weak positive correlation can be observed with 11 of the 14 pupils who completed 12 cards gaining 70% and above. At the other end of the scale the two learners who gained the lowest post-test scores (25% and 30%) had completed very few work cards (7 and 6 respectively).

Appendix L shows each pupil's score for each exercise that they attempted. Figure 6.21 compares their average exercise score with the number of exercises completed and once more a positive correlation can be observed. Only those pupils who completed twelve or more cards achieved mean exercise scores above nine out of ten.

Both analyses show that the highest scores are linked to the increased incidence of map reading opportunities. These findings reinforce the second part of the hypothesis statement; the reason that Maptrix improves map reading performance is that it provides practice in the skill of map reading.

Figure 6.20 Number of exercises attempted compared to post-test scores

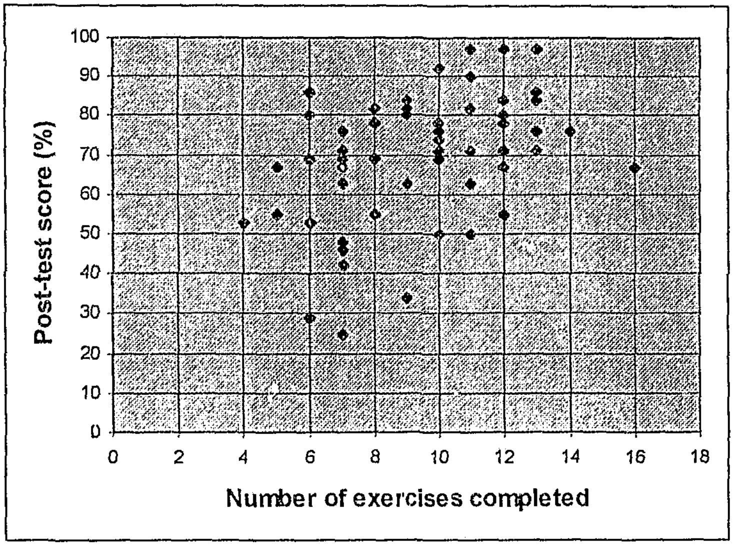
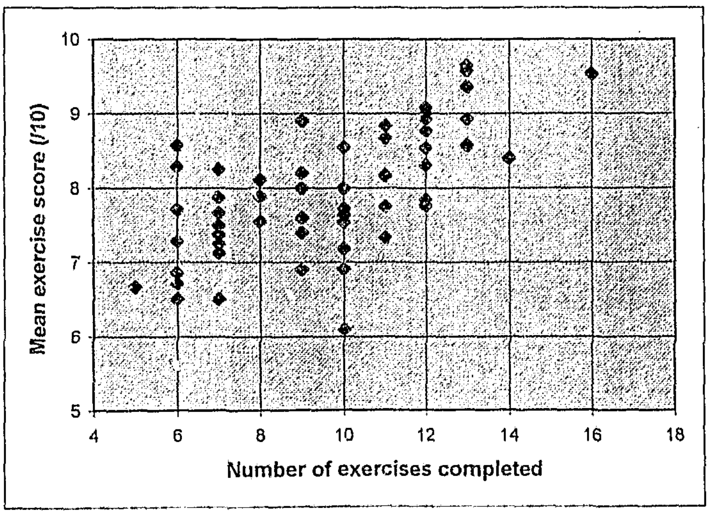


Figure 6.21 Number of exercises attempted compared to mean exercise score



6.5.7 The exercises are of equal difficulty

After the pilot test, a potential error analysis was carried out on all 52 exercises. The results (described in 5.2.5) showed a wide margin of variance (from 3% to 47%) around the mean error score of 18.8%. All exercises were checked to reduce the difference in the level of difficulty. During the classroom trial each work card was drawn repeatedly so, instead of conducting a potential error analysis, the mean scores for all exercises were compared to assess whether the exercises were of equal difficulty (appendix L).

Figure 6.22 Comparison of mean scores (/10) for all 52 Maptrix exercises

Hearts														
Card	A	2	3	4	5	6	7	8	9	10	J	Q	K	Totals
Mean	8	7	7	7	6	8	8	8	9	7	8	8	9	7.7
S.dev	1	2	2	2	2	2	2	2	1	2	1	1	1	0.4
Max	10	10	8	10	9	10	9	10	10	10	9	10	10	10
Min	7	4	4	3	3	4	5	5	7	6	6	4	5	3

Diamonds														
Card	A	2	3	4	5	6	7	8	9	10	J	Q	K	Totals
Mean	8	8	7	8	8	8	8	8	9	9	7	8	8	8.0
S.dev	2	1	1	1	2	1	1	1	1	1	2	1	2	0.4
Max	10	10	10	10	10	10	10	9	10	10	10	10	10	10
Min	2	5	4	6	5	6	6	5	7	7	3	6	3	2

Spades														
Card	A	2	3	4	5	6	7	8	9	10	J	Q	K	Totals
Mean	8	7	8	7	7	7	8	7	8	8	8	8	7	7.5
S.dev	1	2	2	1	2	1	1	2	1	1	1	2	1	0.5
Max	9	10	10	9	10	9	9	10	9	9	10	10	9	10
Min	5	2	5	6	5	5	6	2	5	7	6	4	5	2

Clubs														
Card	A	2	3	4	5	6	7	8	9	10	J	Q	K	Totals
Mean	8	8	8	8	8	8	8	8	8	9	8	9	9	8.3
S.dev	1	1	1	1	1	2	1	1	2	1	2	1	1	0.4
Max	9	10	10	10	10	10	9	9	10	10	10	10	10	10
Min	5	6	6	6	5	4	7	5	5	7	5	7	8	4

The table in figure 6.22 summarises the mean scores for all exercises attempted. With one exception (Hearts 5), the mean score for each exercise was seven out of ten or more, with an overall mean of 7.9. The deviation from the mean was 0,5 or less suggesting that the exercises are not of equal difficulty, but that the difference in level of difficulty is not significant.

The range in minimum scores was greater than that for mean scores; from 2 for Ace of Diamonds and the Two and Eight of Spades to 8 for the King of Clubs. This wide range of minimum scores may reflect the different abilities of the test population when they started the programme. Nevertheless, if the opportunity presents itself to prepare an improved prototype for further testing, these exercises at the top and bottom of the range will be checked once again and rewritten if necessary.

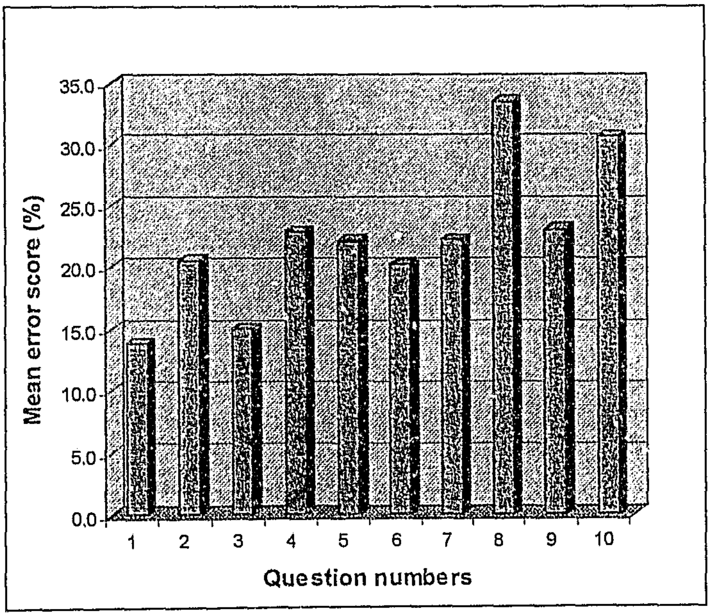
6.5.8 The themes are of equal difficulty

To establish the level of difficulty for each theme compared to the others, the maximum, minimum and mean scores for all exercises per theme are shown in figure 6.22. This again reveals that there is very little difference (0.8) in the mean scores. The highest mean score (8.3 with a minimum of 4) was obtained for Clubs (**urban settlement**) suggesting, perhaps, that the test population found these maps easiest to understand. The lowest mean score (7.5 with a minimum of 2) was obtained for Spades (**landscape**) suggesting that pupils in this sample found these maps most difficult to understand. These findings reflect the outcome of the pilot study where the potential error score for Spades (25%) was almost double that for Clubs (13%). This apparent difference in level of difficulty has remained despite rewriting and reorganising questions after the pilot test. One factor, which may have contributed to the lower scores for the Spades exercises, is the need to use mathematical concepts to understand contours. A possible explanation for the high scores for the Clubs exercises may be that pupils are more familiar with an urban environment. If possible, further testing must be carried out in classrooms in different types of environments to assess mathematical concept development and terrain familiarity as factors influencing map reading ability.

6.5.9 The questions become progressively more difficult from one to ten

After the pilot test all the answers for each exercise were analysed on the basis of potential errors compared to actual errors. This revealed that the last few questions in each exercise did appear to be more difficult than the first few but certain anomalies were revealed. After the school trial a sample of twelve work cards was extracted, consisting of those which had been most frequently selected from each sub-theme. From the pupil booklets, the scores gained for each answer were listed and analysed (appendix M). This was done to check whether the anomalies in the difficulty ranking had been removed by the renumbering and rewriting of some questions. Figure 6.23 shows that although the trend indicates increased difficulty, the progression is not smooth. Question one has proved to be the easiest, while question eight appears to have been the most difficult on the sample of twelve work cards rather than question ten. This suggests that further checking of the questions and answers is necessary if an improved prototype is to be tested.

Figure 6.23 Errors per question



6.6 RECOMMENDATIONS FOR IMPLEMENTING THE MAPTRIX PROGRAMME

Current poor performance in map reading at school must be addressed from a new perspective. Practising is an obvious way to improve most skills. Maptrix provides an opportunity for practising map reading. Some finishing touches are still needed if this programme is to be placed in more schools for further testing. The 52 work and answer cards must be carefully scrutinised once more for ambiguities and corrected where necessary. It appears from both the pilot test and the classroom trial that learners have experienced more difficulties with the exercises based on the theme **landscape** than on the other themes. In order to provide more practice in reading the maps in the Spades series, in which the questions focus on the interpretation of landscape, it may be necessary to offer a few extra work cards (possibly using the joker playing card).

Apart from the cards and the master copy of the pupil booklet, every Maptrix Kit must include a local topographic map sheet. Research in other countries (Sandford, 1986) has stressed the importance of introducing map reading by using maps of the local environment. The analysis of the findings regarding the differences of the difficulty of each theme in the Maptrix Kit, suggest that pupils living in an urban environment find maps of urban areas easiest to read.

Materials for a pre- and post-test should be made available, as well as a teachers' guide. The layout of the pupil booklet needs further attention, especially the instructions, and suitable packaging for the kit must be designed.

6.6.1 The local topographic map sheet

A local topographic map sheet (preferably laminated) must accompany each Maptrix Kit and be displayed prominently in the classroom where the programme is in use. Pupils should be encouraged to identify the school and other constructed and natural features in the local environment. Once pupils are aware of how their own local area is portrayed on the map, they will more likely be able to visualise the landscape portrayed by other map sheets; this is particularly useful for comparative geographic studies. Teachers should be encouraged to use the local sheet f. geography fieldwork.

6.6.2 Packaging and display

The importance of the correct display format was identified after running the pilot test. It is important that pupils can select the work cards quickly and easily. Four trays, one for each theme, worked better than one box, but these took up a lot of space on the teacher's desk. A packaging design is envisaged that links two of the trays to form a base for a flat box which is constructed so as to fold up in the middle to form an A-frame stand. This will hold two sets of work cards, one on each side. The other two trays would be similarly constructed, to form a lid for the flat box (for transporting and storing the kit) but would also fold up into an A-frame stand to hold the other two sets of work cards (when in use in the classroom). The four surfaces of two A-frame stands could be used for the four illustrative posters referred to in the next section on the teachers' guide.

6.6.3 Teachers' guide

Two elements to the teacher's guide are proposed: four introductory A3 posters and teachers' booklet. The teacher should be informed of the principles upon which the programme has been designed and given careful guidance for introducing the programme to pupils. The booklet should include assistance with diagnosing learners' problems linked to the cognitive levels tested by the graded questions in each exercise. Suggestions for using maps for fieldwork and to illustrate a variety of geographic concepts such as the local drainage or settlement patterns could be included. Administrative watch points identified during the classroom trial could be listed. These include how to encourage and use peer tutoring, ensuring that a full range of exercises is available by holding back one example of each sub-theme at the start of the programme, reminding pupils that the combination of exercises is as important in improving their skills as the exercises themselves.

Three concepts need to be explained before the learners proceed with the programme: the alphanumeric grid, the names and structure of the playing card suits and how to use a bar graph. Illustrations for each concept can be produced on three of the A3 posters referred to above. The extra poster can guide the teacher through the step by step process of introducing the programme at the first lesson. Such a system has proved useful in a map reading skills programme for primary schools (Potgieter and Olën, 1993). It is important that the programme is introduced carefully so that learners can be left undisturbed to work on their own without repeated instructions being given to the class (or repeatedly having to ask for guidance).

This research posits the view that the role of teachers of map reading is to manage a learning environment in which

- they have sufficient resources to keep each learner actively engaged,
- they oversee the programme so that each learner follows a course of exercises to develop map reading skills,
- they ensure that learners assess and record their progress (using peer tutoring where possible), and
- they are free to give attention to individuals or small groups of learners who need guidance.

In this role teachers can guide learners even when their own training in map use has been inadequate. Teachers in this situation can develop their own competence by using the programme privately to upgrade their map use skills. Once they feel more confident, they can use the materials creatively to incorporate map study into various components of the geography syllabus using their preferred teaching strategies.

6.6.4 Pupil booklet

The instructions on the front of the pupil booklet (appendix F) must be simplified and presented in a more user-friendly way. The 16 steps appear very daunting and instructions had to be repeated often by the teacher so that pupils knew what they were expected to do. The name should be changed to Learner's Booklet.

6.6.5 Pre- and post tests

Very few pupils completed the pre-test during the school trial. It is obvious that there is not enough time to attempt the twenty-four questions and write out the answers (no matter how short) during one lesson. It is suggested that comparable banks of no more than fifteen questions should be prepared, if the short answer format is to be used again in future school trials. Alternately it may be necessary to use multiple-choice questions.

Apart from monitoring the pupils' progress in their booklets, the teacher may want to measure the overall improvement in the map reading performance of the class. For this purpose, as well as for general testing of map reading competence, it is proposed that the MapAware test map (as in appendix H.1, but now printed in full colour, appendix N) and a bank of multiple choice questions and answers be made available to accompany the Maptrix Kit. Although multiple choice questions are used sparingly throughout the programme to avoid chance indications of improvement, this style of question makes it possible to obtain a rapid and objective assessment of learners' skill levels.

6.6.6 Classroom time required for Maptrix

Eight geography lessons of 35 to 40 minutes were set aside for the Maptrix trial. This was not enough time for all pupils to complete the programme. Two and a half of these lessons were given to the explanation of the programme and the assessment procedures. It is clear that at least two more lessons are needed. A total of ten lessons is assumed to provide sufficient time to run the programme in the classroom during average school periods. The average number of cards completed in the five and a half lessons was 9,1 with the fastest pupil (number 24) completing 16 and two pupils (numbers 51 and 55) completing only 5 (appendix L). It appears that both these pupils were absent for one or more lessons.

Time could have been saved by spending less time describing the link between the themes and sub-themes, and the playing card suits and numbers. Once the first exercise has been completed, the pupils could be involved in discovering the connections between suits and themes. This can be done by directing questions that lead the pupils to identify the twelve sub-themes (using the different background colours) and then guiding them towards an understanding of the geographic concept framework used for the programme. This concept framework will then be reinforced as they work through the map exercises illustrating each theme.

6.6.7 Using Maptrix outside class time

One advantage of the self-instruction programme is that those learners who wish to make up the lessons that they miss can do so in their own time. Senior pupils needing to refresh their map reading skills can follow the programme (with limited supervision) as part of an extra-mural or vacation school programme for examination preparation.

Students selecting geography at tertiary education level, who have not taken this subject at secondary school, may find the introductory geographic concept framework valuable while simultaneously developing the basic map reading skills required for map analysis and interpretation.

6.6.8 The next step – Maptrix II

In the introductory chapter it was mentioned that the self-instruction programme was originally envisaged as a much more ambitious project consisting of 100 work cards to develop map reading, analysis and interpretation. Now that Maptrix has been accepted as part of the Chief Directorate of Surveys and Mapping's MapAware Project, it is hoped that the extension of the self-instruction programme to include the two higher level cognitive skills may be possible.

A linked set of 52 work and answer cards is envisaged. These will include extracts from oblique and vertical aerial photographs and maps at different scales showing the areas selected for the existing work cards. The self-instruction method could be used to devise exercises that go beyond map reading to develop the skills of analysis and interpretation of spatial information. With the rapid development in technology designed to display and manipulate spatially related digital images on computer screens, it is hoped that this medium can be used to develop further instruction materials for South African map users.

6.7 OTHER PRESCRIPTIONS FOR TREATING THE MAPWORK MALADY

At the end of chapter three, steps were recommended for improving school mapwork performance: ensuring availability of local maps, broadening the geographic concept base of learners and increasing the opportunity for practical map use. Maptrix may go some way towards meeting some of these needs but a much broader vision is required if comprehensive treatment for the mapwork malady is to be found.

6.7.1 Responsibility for map user education

Outcomes Based Education offers unique opportunities for stake holders to take responsibility for education and training. By generating standards for accredited national standards bodies (NSBs), moderated by education and training quality assurance bodies (ETQAs), leaders in all fields of endeavor in the public and private sector can ensure that today's youth is being prepared to face tomorrow's challenges (SAQA, undated). South Africa's national mapping organisation (NMO) is already deeply involved with the training of surveyors and cartographers who, together, make maps. Perhaps it is time to become involved in the education and training of cartologers, those who read maps.

6.7.2 Two keys to making maps more readable

Difficulties for novice map users which arise from changes to the map symbols have been highlighted. Anomalies in the map key such as the absence of contour lines and the presence of bridges on supposedly non-engineered roads have been mentioned. The practice of placing more than one symbol per entry on the reference list proved to be confusing for the sample population who tested Maptrix. Many of their errors arose from giving both symbols or giving the wrong symbol when answering questions.

Lack of a map key in their own language makes access to spatial information difficult for many South Africans. All school leavers should be able to read enough information from maps so that they can use them for way finding and route planning. One way to provide this life skill is to ensure that they have a basic geographic frame of reference for understanding a map key. It is recommended that greater attention to detail is paid by cartographers when compiling the map key and by geography educators when teaching its use.

Describing where places are on a map requires the use of some kind of reference grid. British Ordinance Survey maps use a six-figure reference system with grid lines clearly marked on the map. The Universal Transverse Mercator (UTM) grid is used by military authorities around the world, for describing position. This grid is placed over the standard topographic map sheets for use by the South African military confirming the need for this aid to map reading. It is most inconvenient, and for novice map users almost impossible, to describe location without the presence of grid lines on the standard South African 1:50 000 topographic map. The development of the Maptrix programme would not have been possible without the addition of the grid lines at 0,5' intervals on the map extracts. It is recommended that the addition of such grid lines to the topographic map series be investigated.

6.7.3 Improving access to and use of spatial information

Making free local maps available to schools (Clarke, 1998) via the MapPack project is a meritorious undertaking. As yet there is no way to assess whether the maps are being used efficiently to promote map literacy or to acquire spatial information for doing local field work. An education outreach programme is required to backup the MapPack in an attempt to promote the spatial comprehension required by tomorrow's decision makers.

6.8 CONCLUSION

Theories of learning in general and learning to read in particular were consulted. The specific nature of the topographic base map of the South African national series was investigated and its use in geography education reviewed. Principles of instructional design were applied in the task of producing a self-instruction programme for map reading.

The pre- and post-test results show that Maptrix has improved the map reading performance of a small sample population of adult and adolescent learners. This confirms that the self-instruction method can be used to learn to read the South African 1:50 000 topographic map. Although no obvious flaws in the design of the programme were identified, some aspects of programme development need further refinement.

My initial investigation of the problems of teaching mapwork in South African schools has proved to be only the tip of an iceberg. Below the surface of the sea of past indifference lies the real problem. Land reform can't happen without maps. Because of indifference to the poor map reading performance of yesterday's pupils, many adults now lack the knowledge to deal with the spatial information required to solve the land management, land reform and land restitution problems of today. Only the future will show whether the MapAware Project of the Chief Directorate of Surveys and Mapping makes a difference.

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