GRAPHICACY AND THE THIRD DIMENSION, AN INVESTIGATION INTO THE PROBLEM OF POOR PERFORMANCE IN RELIEF MAPWORK IN SOUTH AFRICAN SECONDARY SCHOOLS.

by

MICHAEL StJ.W. BURTON

Submitted to Rhodes University in part fulfilment of the requirements for the Degree of Master of Education.

January 1986

ABSTRACT

Three-dimensional graphicacy is the part of mapwork that appears to be the most problematical. Bartz (1970) says that thinking and visualising in three-dimensional space is difficult enough, but trying to derive notions in three-dimensions, when you have only seen them as they are represented in distorted two-dimensional fashion, is even more difficult. Yet pupils of geography are required to learn such three-dimensional concepts from the two-dimensional distorted map presentations. The geography teacher has an important educational role to play in promoting graphicacy and Balchin (1965), who coined the term, felt that it should be an essential underpinning of an integrated education. The problem is that children perform badly, teachers are not successfully imparting three-dimensional graphicacy skills and as Board and Taylor (1977) indicate, for some time now it has been fashionable to dismiss maps as being irrelevant or useless in geographical research.

This thesis attempts to analyse this reported malady, the problems are exposed and solutions offered. Investigation of the literature, with the aim of clarifying the problems involved, follows four leads. These are the part played by the map as a mode of communication, the physical processes involved in mapwork revealed by work in the realm of neuro-physiology, the process of visualisation in the field of perception and psychology, and finally the stage of conceptual development of the mapworker.

The state of affairs in South Africa is disclosed by an analysis of teacher-directed literature, of examination syllabuses, of text-book treatment of three-dimensional mapwork in South Africa and overseas, of past examination questions, and finally of teachers' views. Experimental exercises have been executed in an attempt to link the key findings of published research to the local scene.

Conclusions are then drawn, and recommendations made for improving three-dimensional graphicacy in South African secondary schools.

PREFACE

The origin of this manuscript lies more than a decade ago when the I was the A-Level Associated Examination Board's Regional Examiner for Matabeleland in, what was then, Rhodesia. The examinination included an oral mapwork section where candidates in person-to-person interview answered questions set. It was clear that the most difficult concepts for candidates to explain were those aspects relating to three-dimensional map representation. At a lower academic level as an examiner for the Rhodesian Certificate of Education (approximately Standard 8 in South Africa) one particular answer was markedly provocative and exemplified the nadir in understanding. The question asked for map evidence of land gradient, and that answer was :

'I can tell that the land is flat because the paper is flat'.

Since immigrating to South Africa and being a sub-examiner for the Joint Matriculation Board for seven years this evidence has been confirmed. The mapwork section, particularly that part requiring three-dimensional thinking is badly answered. When Bailey (1978) reported that contour mapwork skills are the least understood part of mapwork in Britain it was clear that research into the problem of poor mapwork performance in South Africa focused on three-dimensional thinking was necessary.

Most children when asked why the moon is a crescent shape will give as a reason that the earth's shadow has something to do with it.They reason on a two-dimensional plane and it would appear that they cannot visualise the scene in its three-dimensions.

My hypothesis is that there is a link between inability to think three-dimensionally and inability to perform well in contour mapwork. The assumption that people who can think three-dimensionally can also perform well in contour tests appears to have some basis in the concept development theories of Piaget and Bruner. Research in the sciences, (Talley, 1973), mathematics and geometrical drawing (Lappan et al, 1984), and the arts (Edwards, 1979) since the 1970's also appear to stress the importance of understanding three-dimensional thinking as a key for introducing such concepts as cells in biology, cubes in mathematics, and molecule structures in physical science. The same barrier, an inability to rotate abstractly a two-dimensional image of a structure through ninety degrees, faces educators in a variety of disciplines at the stage of secondary education when these important concepts are introduced. Perhaps there is a barrier to be broken through and perhaps it is a developmental one. In the world of geography it manifests itself in contour mapwork and research in the 1980's must ascertain the best method of stepping over this two-dimensional/three-dimensional barrier.

ACKNOWLEDGEMENTS

The most valuable assistance and direction received has come from Dr. E.A.G. Clark (Rhodes Department of Education) and this despite his suffering a considerable set back due to ill health. My grateful appreciation goes to Arthur Clark for encouraging me through the course, for his expertise, scholarship, academic integrity and friendship.

Valuable assistance was given to me by Dr. Rob Fincham and Mr. Oakley West (Rhodes Department of Geography) when Dr. Clark was indisposed and their helpful suggestions, interest at the outset, and the compelling way that they got my nose to the grindstone are very much appreciated.

I wish to thank the teachers of the Grahamstown schools who all responded conscientiously and promptly to the eleventh-hour questionnaire and their views were particularly pertinent and helpful. At Kingswood College my appreciation goes to Mr. Gordon Todd (Headmaster), and Mr. John Lees (Headmaster of the Junior School) for their co-operation during the period of research and to the staff members of both schools who gave me time to investigate experimentally with pupils in their classes. Particular assistance has been given to me by Philip Collett who brought me into the world of the micro-computer word-processor and made one readily available to me so that I could do all the work for this thesis and store it on disk and then have it type out my final copy. Dominic King assisted me by giving advice on the printing of this manuscript and I wish to record my appreciation to him for making the Kingswood printing facilities available to me. There were over two hundred and fifty pupils at Kingswood who did tests from time to time and accepted the task even though they did not really know what it was all about. I was priveleged to have their co-operation.

Last at Kingswood, but not least, my gratitude goes to my long suffering family, to my wife Noreen for her encouragement and help with the proof-reading and to my children Andrew, Simon, and Deborah for spending a lot of holiday time helping me to print out and collate the manuscript in the Kingswood Printing Room.

Finally, I wish to thank the Human Sciences Research Council for financial assistance. Opinions expressed in the text are solely mine and do not necessarily reflect the views of the Human Sciences Research Council.

To my wife Noreen for her encouragement and fortitude when my tasks of fathering housemastering, schoolmastering, and researching conflicted with each other.

TABLE OF CONTENTS

LIST OF FIGURES

PAGE

LIST OF TABLES

INTRODUCTION

The term graphicacy was first used in an article by Balchin and Coleman (1965) and in it they indicated that there are four main orders of communication - literacy, numeracy, articulacy and graphicacy. Balchin defined graphicacy as the art of communicating spatial information that cannot be conveyed by verbal or numerical means. In geography this order of communication with its special skills is particularly pertinent in the sphere of mapwork. The problems involved are stated clearly below.

> "The teaching of contour-map reading is generally regarded as one of the most difficult problems the Geography Teacher has to face. The ability to visualise the solid reality from the two-dimensional map often seems incapable of attainment by a majority of the class. But much of this apparent difficulty is probably due to a wrong method of approach. Just as modern experiments in teaching children to read have greatly facilitated and simplified the process of reading, so it is possible that experiment may discover a method by which contour-map reading may be made as simple a process for the average pupil as reading a book. There is opportunity for educational research in this direction."
> (Memorandum on the Teaching of Geography, 1939, p.174)

In the nearly fifty years that have passed since the Association of Assistant Masters in Secondary Schools issued their Memorandum in Britain, it would appear that not a great deal of research follow-up has taken place. The aim of this research thesis is to investigate the literature so as to analyse the present state of affairs and to address the following questions concerning three-dimensional aspects of mapwork at secondary school level in South Africa :

a. What are the appropriate skills that should be developed?
   This involves looking at maps as communication systems and then focusing on three-dimensional aspects. It involves understanding perception or visualisation and neurophysiological considerations.

b. When should they be taught? (When is the map-user ready?)
   This involves investigating relevant aspects of Piaget's and Bruner's theories of intellectual development.

c. How could these skills be improved?
   This involves investigating research findings in the field of mapwork skills to test by what means they should be taught.

It requires looking at how they are taught at present, and how this could be improved (a series of model strategies), and how they are tested and examined in the South African setting.

My assumptions are that at present three-dimensional mapwork skills are introduced haphazardly in South African schools with no real reference to the receptivity of the pupils and that the examination of mapwork skills is likewise haphazard and lacks structure. My experience as an Examiner for the Associated Examining Board A-Level examinations in Rhodesia and as a Sub-Examiner for seven years for the Joint Matriculation Board, leads me to the view that in public examinations the mapwork questions are answered badly and with little understanding.

It is commonly held that map reading should be a simple exercise because "to most people, using a map appears to be a straightforward and quite natural task." (Keates, 1982, p.1). But this is a matter for debate as Carswell (1971, p.40) notes,

> "First, we overestimate our success in teaching map reading skills. Second, we tend to underestimate the map reading abilities of children. Third, our teaching of map skills mitigates against the operation of spatial mental ability. In short, there is little understanding in the educational and geographic communities of children's ability to comprehend maps or the mental processes children use to decode maps."

Boardman (1983) defends this view and also warns that not all map reading is simplistic as an understanding of the representation of height, slope and relief on a map is probably the aspect of graphicacy which is most difficult to develop in most children. The paradox of this state of affairs is that the apparently simple act of looking at a map in fact includes a highly complex sequence of processes. To demonstrate this and to address the questions posed (on p.1) I propose to isolate certain problems by considering a 'simple' three-dimensional mapwork example. This will serve to introduce an outline of the sequential framework that I have used in this research investigation.

<u>The example problem posed.</u>

A simple task to consider is what procedures are involved in the mapwork calculation of the uphill gradient of a small river valley from the school buildings at X to the hut at Y on the map, over the page, by a secondary school adolescent. It appears at the outset to be a simple operation and yet it incorporates a number of complex operations that are not always fully understood and are perhaps taken for granted.

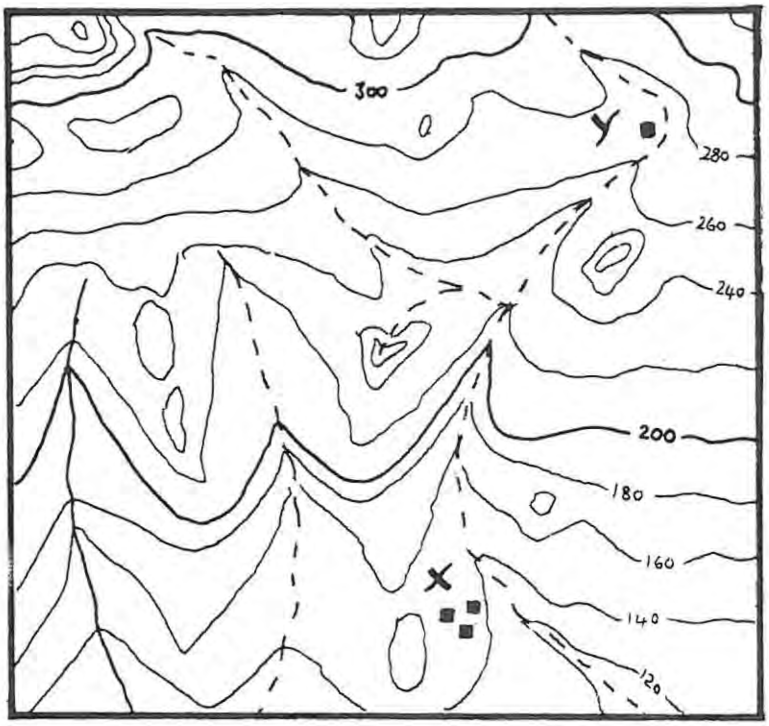


Figure 1.1. A map to investigate the procedures involved in the mapwork calculation of a gradient.

A full account of how information is acquired from the map must include the following points and take into account,

i. the map as an information store in the map-reading operation,
ii. the neurophysiological processes involved in mapwork,
iii. the process of perception in the map-reading task, and
iv. the cognitive processes of learning and remembering, and the stage of intellectual development of the young user.

The processes involved in calculating the river valley gradient have been isolated above for the purposes of presenting a clear analysis but this does not imply that the processes themselves operate in some simple separate sequential manner, rather they are complex and interlinked.

(a) The map as an information store in the map-reading operation.

The analysis focuses first on the map itself as a variable in the interaction. The map-user searches until he finds a large-scale topographical map for the area in which he believes the river valley to be, and this is usually on the scale of 1:50 000. He has to choose a map with a suitable scale and content. The map presents certain images that the user must be able to read or recognise. The map user makes use of the visual clues provided by the map symbols to perform his map operation. He must know that the blue line on the map represents a river. The specific river that the map-reader seeks is classified into a broad category river (and depending on the nature of the symbol it may be further classed as a perennial or non-perennial river). The brown lines form patterns of the landscape and the map-user must recognise that a V-pattern represents a slope of land either in spur form or valley form. He must be able to differentiate between upslope and downslope patterns. The map-user will find it difficult to visualise the valley without being aware of map-scale, and converting map distances into approximately true distances. Clearly there are a great number of complex map reading skills that he must master before the map-user can read or interpret the map. It is a document loaded with symbols and embedded patterns.

(b) The neurophysiological processes involved in mapwork.

Mapwork embraces a range of extremely complex neurophysiological processes in the brain of the young mapworker who is looking at the problem map. The brief description below merely hints at the complexities located in one of the links in the chain of the map-reading operation, a very complicated link about which a lot is still unknown. An interesting sequence of intricate events is mobilised when light forms a pattern on the retina of the eye. The physical process is then translated into a psychological response by a flow of energy from retina through optic nerves to the brain. Closer investigation of the word 'translated' as used above, (Neisser, 1968) reveals further intricacies. The millions of rods and cones in the retina are photo-receptors and the effect of light, or a change of light intensity above threshold, is to decompose photopigments, which in turn cause an electric signal, which is eventually transmitted to a ganglion cell. Then each ganglion does not simply transmit an impulse from a single point on the retina, but summarises the signals received from a number of inputs. Clearly the description above is necessarily oversimplified, for the process is a major field of research and while it is not central to investigating map-skills it must not be overlooked as it is very much part of the complexity of mapwork.

(c) The process of perception in mapwork.

The young mapworker must now perceive three-dimensional landscape reality from a document that displays representative symbols on a two-dimensional surface. The map presents a graphic image of the river with its position, course and extent marked out and its relationship in space with other relief features. Because all this information is presented in symbolized and miniature form the map-user can perceive the valley represented on the map. Perception involves the twin processes of detection and discrimination In other words the symbols on the map must be a sufficient stimulus to make them detectable and the symbols must be sufficiently different from one another to allow easy discrimination. This too is a complex process and many maps exist in which it is not possible to carry out discrimination with confidence (particularly if there is no colour).

The particular mapping task being investigated focuses on the ability of the map reader to perceive a three-dimensional form (the river valley) from a two-dimensional plane (the map) and this requires him to mentally adjust the contour lines through ninety degrees in his mind. Analysis of this procedure is a vital part of investigating map reading ability of young map users. A further difficulty is that the journey from X to Y on the map is not a straight line journey but it is one that 'meanders' with the river.

For real meaning in perception it is now important to assess the additional processes of identification and recognition. There is no river name on the map index so the map-user has to search for the river or the river name within the map detail. He has to realize that this information is depicted in the colour blue. This is an act of cognition because the blue line that he looks for is a symbol and a symbol is a subset of signs which are used in human communication. To locate the valley he has to identify the V-shape of the brown contour lines and he has to discriminate their pattern by their alignment and numbering. Identification means that the symbol looks familiar but recognition takes this one stage further and implies familiarity of a geographical feature.

Detection, discrimination, identification and recognition can be regarded as the preconditions for map use. Beyond this is the further stage of interpretation whereby the map information is processed so as to deal with the particular map-reading task. Interpretation varies with individual skill and knowledge of the map-user. All in all, the perceptual field, too, is one that attracts research and is very much part of an investigation into map-reading.

(d) The cognitive processes of learning and remembering, and the stage of intellectual development of the young user.

So-far this analysis has taken no account of the range of abilities found in the adolescent secondary school setting. The pupil at the beginning of his secondary schooling will find the task an extremely difficult one while the senior will find it a simple one. Herein lie the differences between theorists Piaget and Bruner who have tried to show that pupils pass through a predictable sequential pattern of intellectual growth. The map user has made use of visual clues displayed by the map symbols. The ability to respond to the map, to make inferences from map evidence, and the amount of knowledge that can be recalled, will vary from person to person. The process of acquiring this knowledge is cumulative and finding the place on the map is therefore affected by the map-user's experience in the operation and his stage of intellectual development.

(e) Summary.

Without expanding any of the processes separated above, it is clear that the map displays the world in a complex kaleidoscopic flux of impressions which has to be organised by our minds. This analysis of the processes involved in the simple map-reading task, (introduced on page 2) has revealed that there are four major links in an operation chain to solve the problems of relief interpretation. First there is the map itself with its symbolic representations of the real world. The second link in the chain involves neurophysiological processes that occur in the mapworker's brain. The third is the perception link, the process of visualisation and cognition and the fourth link is the conceptual link of the user and his level of conceptual development. The four links form the framework structure of the literature review that follows.

CHAPTER 1

PREVIOUS RESEARCH ON RELIEF MAPWORK.

1.1. THREE-DIMENSIONAL MAPWORK AND THE SKILLS INVOLVED.

Emphasis is now placed on the literature of research findings surrounding each of the four links outlined in the introduction. The following survey is necessarily broad because the search in the fields of cartography, neurophysiology, the psychology of perception and then concept formation has revealed a wealth of literature. The review investigates each of these fields and then focuses on seven selected studies considered to be key studies. These in turn form the basis for the later experimental investigation.

1.2. CARTOGRAPHY.

The focus is placed on the map, what it communicates, how it exhibits the third dimension, the map as a communication system, the concept of graphicacy, and the problems of understanding maps.

1.2.1. What topographical maps communicate.

A map communicates space (Unwin, 1981). It is a storage medium that has scale, projection and a set of abstract signs. It is a spatial document, and it is the communication of spatial concepts in an abstract manner that requires skills and a certain level of intellectual development. This level, or stage, of development embraces a perceptual as well as a conceptual level of attainment. The key to understanding maps, therefore, is a visualization of space; space two-dimensional and space three-dimensional.

Space is difficult to define and it is a concept debated by psychologists and philosophers (Richards, 1974). The whole practice and philosophy of geography depends upon the development of a conceptual framework for handling the distribution of objects and events in space (Harvey, 1969). Among the many concepts employed by geographers, regardless of their philosophical stance or methodological persuasion, the most central to their enquiries is the concept of space. Since the 1950's the subject has experienced a shift to a relative spatial context, which is probably the most fundamental change in the history of geography (Abler, Adams and Gould, 1971). So central is space to geographical thought that there have been many calls for re-examination of the concept. Gatrell (1983) presents a clear analysis for geographers and illustrates a variety of spaces that may be created and depicted graphically but any attempt to define space soon exposes it to be an extremely complex concept.

Numerous experiments conducted over many years by Piaget and associates have shown how children's spatial understanding develops gradually and passes through three stages : topological, projective and Euclidean. More recently Catling (1978a) has shown very clearly, how these forms of space understanding are represented by children in a series of four diagrams copied below.

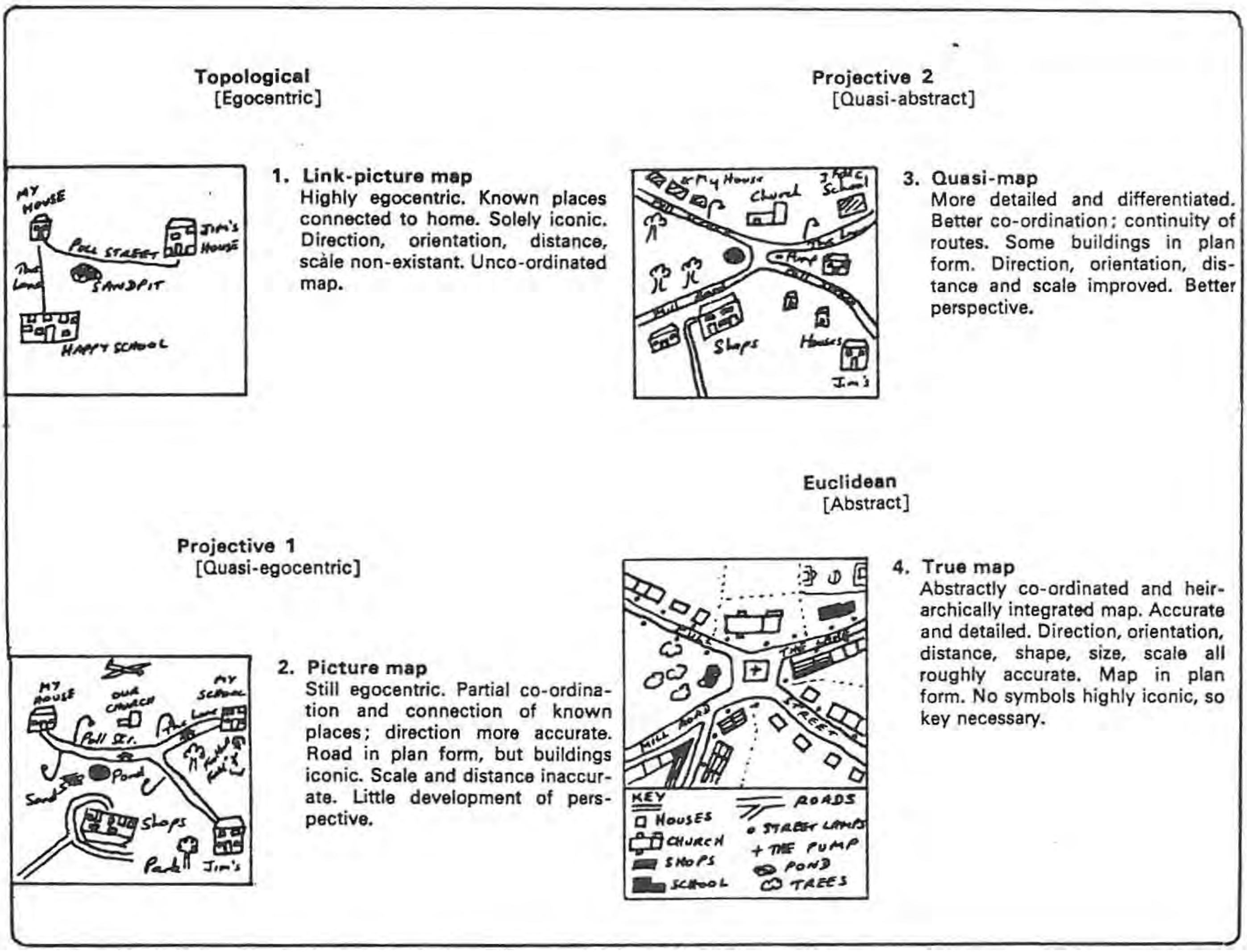


Figure 1.2. A developmental sequence of cognitive map representation.
(From Catling, 1978)

1.2.2. How topographical maps exhibit the third dimension.

Catling (1978) notes that it is only at the Euclidean stage of understanding space that the mapworker is able to really understand the third dimension on the map as displayed by contour patterns. On the South African 1:50 000 topographical map series contours are shown as thin brown continuous lines, broken in places to allow value labelling. The labelling is always done upright upslope so as to aid interpretation of 'up-slope' and 'down-slope'. Phillips (1979), however, investigated this assumption and he found that it is clear that the orientation of the contour labels is not helpful to experienced map readers.

On South African maps the vertical interval is 20 metres on metric maps and 50 feet on the older Imperial unit maps. The fourth or fifth line is thickened (every one 100 metres or every 200 feet) to aid interpretation by acting as a marker. There are five special things to notice about this way of representing relief:

a. Contours show an absolute value of the landscape surface
b. By their spacing they indicate gradient or slope.
c. The base datum line for the vertical scale is mean sea level and this is a constant value. It also allows mapping below the base altitude.
d. The view presented is orthogonal, or as if from an infinite position above.
e. In order to draw contours one needs to know a great deal about the surface variations of the real landscape.

1.2.3. Maps as communications systems.

Proponents of systems analysis (Coffey, 1981) forward the view that the map's important contribution is in providing a communication system. Robinson (1978, p.4) states the case succinctly,

> "Designed graphic expression is a basic form of communication among humans. All evidence points to its existence very early in the development of man and it is known among most primitive people."

Underwood supports this viewpoint and argues that in teaching our pupils to read and interpret maps, we are making available to them 'an efficient and valuable communication system.' (Underwood, 1981 p.54)

The literature search has found that there has been much recent cartographic focus on the map as a system of communication (Kolacny 1969; Koeman 1971; Ratajsky 1977; Robinson and Petchenik 1977; Keates 1982; Boardman 1983). Attention has been directed to the relationships between the activities of the map-makers (or cartographers) on the one hand, and the map users (or recipients) on the other, with the map as the central focus of the communication system. Ratajsky, (1977) maintained that cartography should be regarded as part of the 'informatics', or the new large science of communication. It is significant that this view would place the contour map at the fulcrum.

Based mainly on the ideas of Board (1967) and Kolacny (1969), Ratajsky produced a model system of cartographic transmissions and, as with all systems analyses, the signals transmitted by the map system can be represented in a flow diagram. To illustrate this a typical communication network in its simplest possible form is shown below :

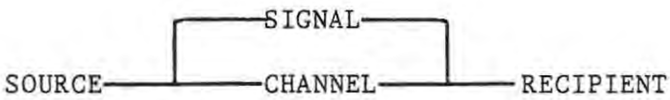


Figure 1.3. Fundamentals of a communication system
(Source : Robinson and Petchenik, 1977, p.95)

Keates (1982) and Boardman (1983) illustrate a generalised model system of communication through maps and here the source is the real world, the encoder is the mind of the cartographer who employs symbols to increase efficiency. The channel or signal is the graphic pattern, the decoder is the mind of the map-reader which decodes the message, and the noise is the distracting information that interferes with his attempts to focus on the pattern.

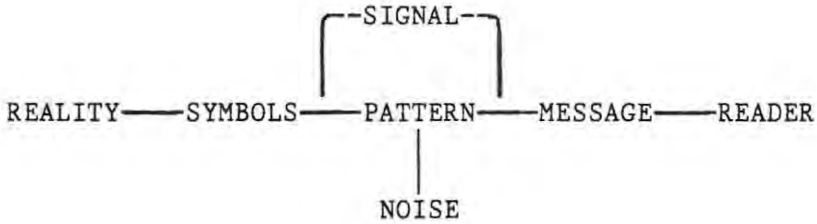


Figure 1.4. The basic concept of the system of cartographic communication.
(Source : Boardman, 1983)

There are some sceptical views of the oversimplified communications systems model, notably by Robinson and Petchenik (1977) who point out that when the cartographic communication process is analysed in detail it is evident that it departs significantly from the general model.

It is apparent that the process of decoding by the map reader has two components and they are identification and comprehension. Boardman (1983) says that these processes develop slowly in children throughout the concrete stage of thinking. The language has to be learned slowly and Bailey (1984, p.62) spells this out,

> "Learning to use maps is akin to learning to play the piano : much rather dull work has to be done before there is any pleasure in it. The sheer difficulty of merely reading maps should never be under-estimated. In schools, the map reading problem is ever-present, even in an 'academic' sixth form."

The difficulty of map reading in the light of a communication system approach is perhaps as Morrison (1974) observes, that if the map reader is not fluent in the language then communication breaks down. It is clear, therefore, that the emphasis in research has shifted from the map as a static graphic display to the cognitive and perceptual activities of the individuals who interact with the map. Robinson and Petchenik (1977) reflect this shift away from the operational aspects and focus on the substantive aspects, shown in diagram form below :

C1 C2 C3 C4

REAL WORLD ——— CARTOGRAPHER'S CONCEPTION ——— MAP ——— PERCIPIENT'S CONCEPTION

Figure 1.5. The cartographic communication system with emphasis upon the conceptual aspects.

(Source : Robinson and Petchenik, 1977, p.99)

Here the cartographer's (selective) conception of the real world (C2) is the message to be transmitted, the map (C3) is the coded signal, and the percipient's conception (C4) is the message received. The (C1) to (C2) transfer is the one side of the interaction that needs further research as does the (C3) to (C4) transfer.

If a map is considered to be a communication vehicle, or system, it proves to be much more complicated than the simplified diagrams described earlier, suggest. It is generally agreed that we do not perceive the elements of two-dimensional (and even less of three-dimensional) displays in any strict sequence, but in the form of a Gestalt, and it has been shown that there are many of the view that, the value of the simple communication model as a basis for examination of the relationships between map-makers, maps and map users, is largely questionable because there are so many variables. For example Roberts (1962) tried to quantify the information content of a map and concluded that the average large scale topographic map may contain anywhere from '100 to 200 million bits of information'.

Analysis of 'map language' is clearly most difficult when considering the third dimension of the landscape displayed on a two-dimensional plane. However, further research into the principle that a map is a communication system may yet reveal that this is a valuable approach. Betak (1975, p.2) sums up this position,

> "It has been well argued that man's effort to represent three-dimensional spatial arrays, on the two-dimensional surface of of paper, canvas, or wall has the character of an arbitrary linguistic convention, and that it is a language that has to be learned like any other."

1.2.4. Graphicacy and the skill of using a map

Balchin and Coleman (1965) coined the term 'graphicacy' and emphasis is now focused on this concept. Balchin's emphasis is clear.

> "It is hoped that the concepts of graphicacy and ingraphicacy will be taken up and developed by educationists, to mould the vague idea of visual aids at large into a more integrated goal of education, and to carry it down into the earliest stages to take its rightful role as one of the essential underpinnings."
> (Balchin, 1965, p.85)

Balchin's claim is that 'graphicacy' is as central to geography as the syllable graph is central to the word geography. So central to the core of geography is graphicacy that it gives the subject its essential ethos. He gives the concept a wider application as an underpinning of a wider education. It is important, therefore, to investigate this concept with particular reference to contour mapping. He used Guilford's (1959) grouping method of reducing the many different aspects of intelligence into four main types. Spatial ability is the first of these, it is the first form of intelligence to evolve. Balchin's summary triangle diagram, copied over the page, simplifies this viewpoint and underscores the importance attached to the concept.

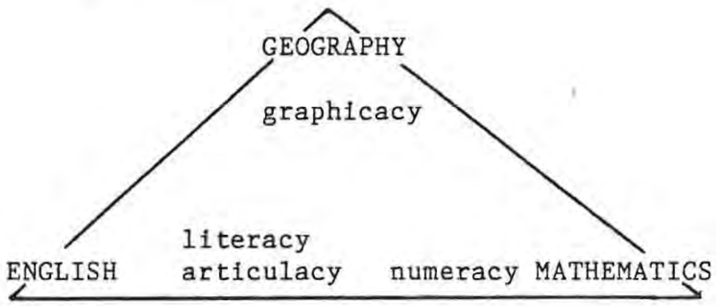


Figure 1.6. Graphicacy as an underpinning of education.
(after Balchin, 1972, p.194)

His basic plan of school subjects for the well-educated person argues that Geography should rank with English and Mathematics as a foundation school subject.

Spatial ability and graphicacy, have a psychological base, and the foundations of graphicacy encompass intellectual development which is related to the stages of understanding topological, projective and Euclidean space. (Boardman, 1983)

W.E.Blake (1979) has drawn attention to the need to develop graphicacy or spatial skills in the context of the cognitive abilities of the map user, and to correct the understandable overemphasis on linguistic or left-brain functions of the human brain. He suggested that geography is not only a spatial study based on locational phenomena, but also an educational tool to enhance the process of right-brain thinking.

Underwood (1981) investigated the relationship between visual-spatial ability and map-reading skill so as to explore the role that the geographer has to play in encouraging the acquisition of one of the basic modes of communication. He has to be the forerunner in the development of the pupil's spatial abilities. She tested 55 fifteen-year, and 11 seventeen-year-old English schoolgirls. A standard test of visual-spatial ability was set and a map-reading test that involved isopleths. Skills tested included the ability to judge relative heights, estimate height, interpret the shape of the land, visualize landscape, and to recognise the shape of the land. The results were shown as correlations between visual-spatial ability and map-reading skills. The pupils showed a trend of controlled experience overcoming the influence of spatial abilites in map-reading tasks. This alone justified Underwood's study and justified the inclusion of such transferable spatial skills training in the school curriculum.

1.2.5. Focus on the three-dimensional aspect of graphicacy.

Bartz (1970) assumed the role of devil's advocate by saying first, that maps are very important and then that in spite of the fact that educators say that they value maps and mapping, evidence to the contrary is provided by student performances. By adopting this approach she raised some interesting and difficult questions, (Jones, 1982), among them that although mapping is of fundamental importance in our culture and value is placed upon teaching about maps and mapping, are the objects being met? Bartz highlighted the problem of three-dimensional graphicacy in school mapwork at secondary level:

> "Thinking and visualizing in three-dimensional space is difficult enough, but trying to derive notions in three-dimensions, when you you have only seen them as they are represented in distorted two-dimensional fashion is more difficult still."

The present investigation focuses on the one aspect of graphicacy that appears to have been overlooked, or given insufficient emphasis by researchers, that of third dimensionality. Most psychological research investigation has shown a focus into spatial ability, on two-dimensional views or perception of depth analysis, oblique views. But the topographical map invites its own research because it requires a capability of three-dimensional thinking A map interpreter has to perform the skill of mentally turning an overhead view of a map, with its abstract symbols (usually contour lines) to a side view or one of elevation, in order to 'understand' the solid reality of landscape that the map is portraying. An understanding of the representation of height, slope and relief on a map is probably the aspect of graphicacy that is most difficult to develop or grasp.

It is a matter of controversy as to when this aspect of mapwork should be introduced to pupils. Satterly (1964) is of the view that, it is too lightly assumed that the child has an idea of the reality behind the map, and he doubts the value of introducing mapwork at primary school at all, whereas Blaut and Stea (1971) take the opposite view and argue that, pre-literate children of five and six can deal with map-like representations and display immense pleasure in doing so. They rather promote an earlier introduction of contour teaching but before accepting either viewpoint it is necessary to investigate some of the problems of understanding maps.

1.2.6. Problems of understanding maps.

Two experienced teachers present valid and parallel views. Bailey (1974, p.32) says,

> "Maps are highly selective and conventionalised representations of the real world, and their interpretation demands of pupils a considerable feat of imagination and the mastery of difficult conceptual skills."

Boardman's (1983, p.16) view is that maps present considerable perceptual problems for children because they involve translating information about large areas from the symbolic form into a meaningful conceptual form. It is perhaps useful at this stage then, to present a list of map characteristics that make mapwork difficult.

a. Selectivity.

No map shows everything and the selection of data mapped can be a source of bewilderment to map readers. It is a difficult concept to grasp at first that a sheet of paper with a map printed on a scale of 1 : 50 000 represents the landscape that can be seen around. The Teaching of Geography (1956) reports that, 'it is too lightly assumed that the child has an idea of the reality behind the map.' A pupil, when asked to draw a map of the surrounding landscape, will try to include everything that he sees and he will find it difficult to be selective.

b. The overhead view.

This convention makes it difficult for the reader to visualise the landscape with which he is normally a part with a side view. The concept requires co-ordinating different perspectives and mental re-orientation in a plan view of a whole landscape. Shepard and Metzler (1971) investigated this three-dimensional thinking by adults, and found that they mentally rotated cube-object combinations abstractly through ninety degrees with great accuracy. Cooper and Shepard (1984), confirmed this finding but Lappan, Phillips, and Winter (1984), found that with three-dimensional mathematical rotation visualization exercises children aged 13 to 15 were not nearly as successful.

c. Map symbols and conventions.

Conventional signs and symbols are not difficult to learn yet there is some confusion in recognising those that are similar in shape. Bailey (1974) notes that colour which appears logical to the teacher (such as blue for water, green for vegetation, red for roads, and brown for relief drawing) may also cause confusion with pupils who do not see the logic. Charlton (1975) reported that young children readily grasp symbolism if they use their local areas and large-scale maps. McGee (1982) also showed that young children have a surprising capacity to identify map symbols 'even though no previous study of them had been made.'

d. Contour weaknesses.

There are three major weaknesses in contour depiction of relief that need to be taken into account when interpreting contour maps (Boxhall and Devereux, 1972). First the vertical interval chosen looks very different on a different scale map. But since this investigation focuses on the 1:50 000 scale series in South Africa the vertical interval is constant. In diagramatic form the same slope shown below looks very different according to the horizontal scale used.

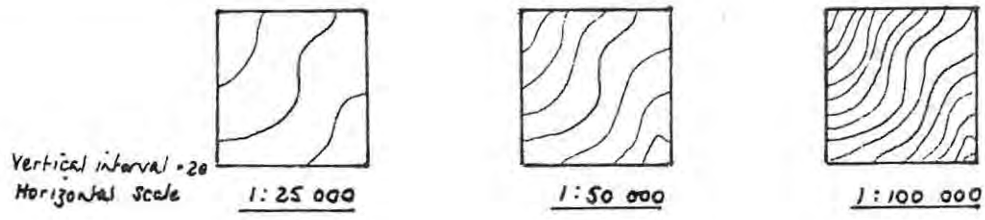


Figure 1.7. The effect of horizontal scale on contour display

A second point to consider is that the effects of relief can be very complex. Using the same contour interval for flat plain landscape as steep mountainous landscape can produce the effect of failing to pick up significant features on the plain or overcrowding the contours on the steepest slopes. Again this problem shows up best diagrammatically.

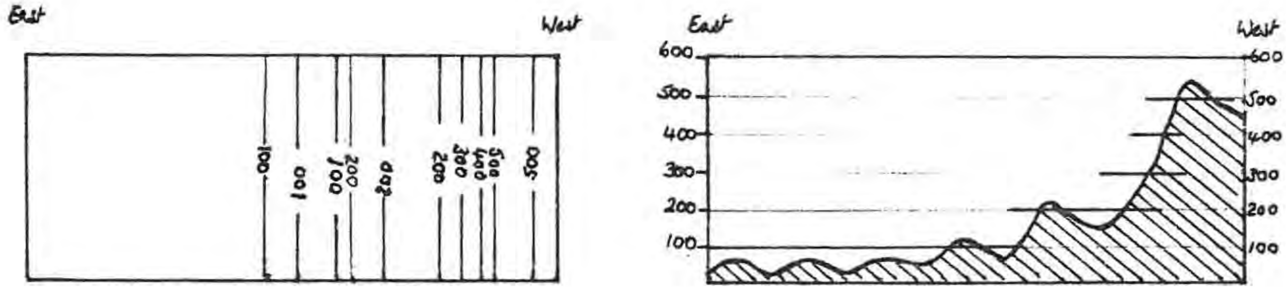


Figure 1.8. The importance of correct vertical interval on a contour display.

The third difficulty is illustrated below. It is a filter difficulty where the contours act as filters according to the relationship of the feature height, altitude and contour value. The small hill field at the lower elevation shows up whereas the small hill field of the same dimensions higher up is missed.

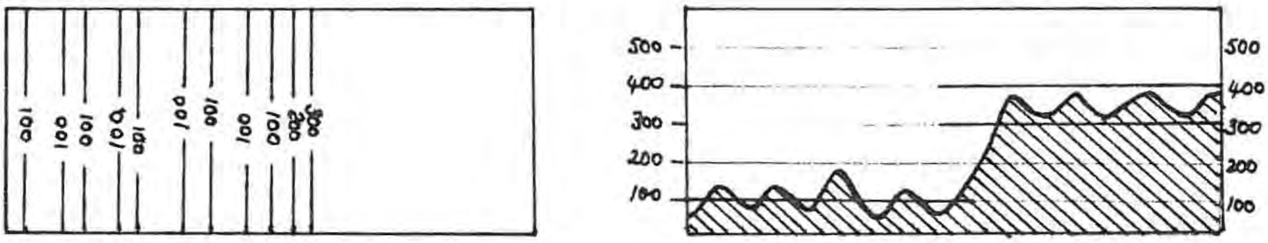


Figure 1.9. The filter problem in contour displays.

e. The difficulty of the profile.

One must conclude that one needs a trained eye to gain a good impression of relief. It is difficult to visualize the height dimension of a landscape map by reading symbols on a two dimensional plane. This is because in nature we are used to viewing the landscape from a side or an oblique viewpoint. To help visualize the third dimension of a landscape surface a profile technique can present a side-view of the landscape. A profile cannot be read or interpreted directly off the map but it has to be constructed separately.

A profile can be drawn as a straight line in the form of a cross-section or equally it can be an irregular line such as a river's long profile (or thalweg). The main problem encountered in constructing profiles is with the concept of vertical exaggeration (Worth, 1978) whereby the vertical scale is emphasised. If the horizontal and the vertical scale is drawn on the same scale the relief appears so flat that analysis is made difficult. On the other hand if the vertical scale is excessive a landscape of gently rolling hills will look like an Alpine scene, and the profile will thereby present a totally distorted image. The ratio of horizontal to vertical scale is an essential aspect of visualizing the third dimension using the profile technique.

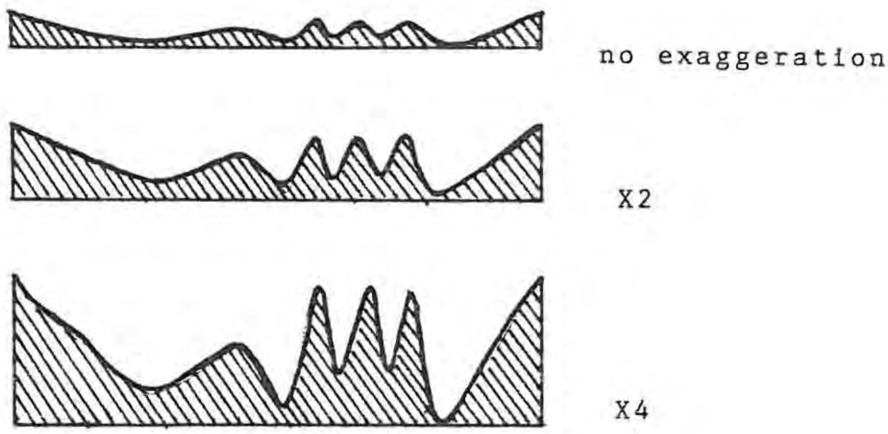
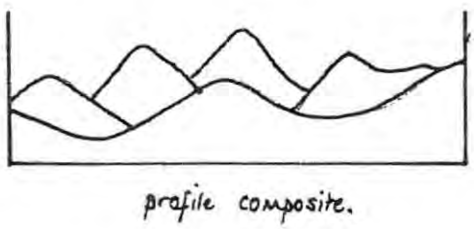


Figure 1.10. The importance of vertical exaggeration scale in a profile.

A profile gives only a single line view and it is therefore very limited as a technique to help visualize the full three dimensional landscape. To enhance the technique several profiles can be superimposed or better still a composite of profiles plotted as if on a horizontal plane can give view of depth. By offsetting a series of profiles a three-dimensional block view adds perspective to the three-dimensional view.



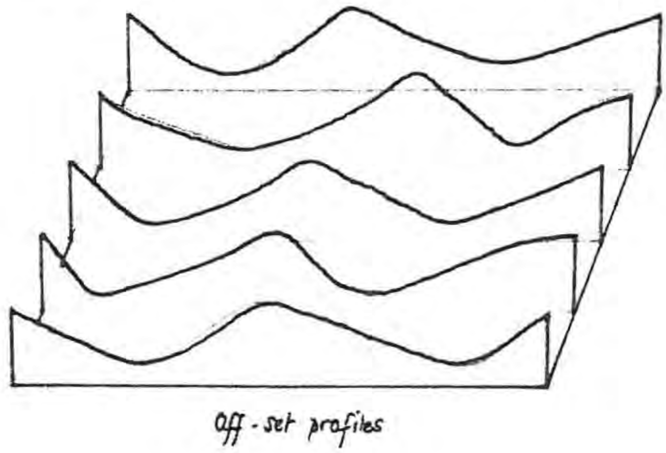


Figure 1.11. The technique of offsetting profiles

f. The problem of slope.

Contours can imply slope changes by the pattern of their proximity. With experience a map reader can gain a good visual impression of slope, which is perhaps the most important property of any scalar field. The slope is the rate of change in vertical rise with horizontal distance and can be expressed as an angle or more usually in 1:50 000 map interpretation as a ratio of height gained to distance travelled horizontally. Slope mapping is a subject with strong mathematical bias and the literature on the topic is full (Dickenson, 1979 ; Monkhouse and Wilkinson, 1963).

g. Relief and contours.

The representation of relief by contours implies a whole series of underlying concepts that can be very difficult to grasp even if the principles are learned and known. The most exhaustive study involving 40 000 responses done by the Geographical Association (1941) showed that contours were not successfully introduced before the age of ten years but after that age there was a regular predictable improvement in performance. Satterly (1964, p.163) emphasised the difficulty of contours,

> "Much greater difficulty is experienced, however, when contour reading : indeed the ability to visualize the solid reality from the contours is not attained by many pupils of school-leaving age."

Boardman and Towner (1979) showed that with a sample of 578 fifteen to sixteen year olds many had an incomplete understanding of what contour maps represent. Public examination answers in South Africa that interpret relief patterns show this very clearly. Thurstone, (1944) linked the problem of reading contours with the difficulty of seeing embedded or hidden shapes.

h. Scale.

This is another difficult problem, as pupils find it difficult to visualize distances and heights from map reading. The capacity has to be developed gradually over a period of time,and must relate to experience in the field. Salt (1971) suggested that the age of twelve is the soonest that scale should be introduced. Towler and Nelson (1968), also investigated the concept of scale at elementary school level and they too, concluded that most children do not develop a sense of scale before the ages of ten or eleven.

i. Spacing of objects.

Children often experience difficulty in the spacing of objects in the visual field in relation to one another. Satterly (1964) reports that there is sometimes confusion with left and right and there are errors of spatial arrangement and proportion.

It is clear that contour mapping has an overload of separate difficulties any one of which can trap and delay a pupil who is learning the concepts for the first time.

1.3. NEUROPHYSIOLOGY

The focus of investigation now shifts from the map to the physical processes that occur between viewing the map with the eye and receiving the image in the brain of the young mapworker.

1.3.1. The neurophysiological processes in using relief maps.

Mapwork naturally relies on the neurophysiological process of vision and the process of vision is in itself a very complex process. The following account relies mainly on the works of Young (1962), Neisser (1968), Gazzaniga (1972), and Keates (1983). 'Seeing' like walking down stairs is taken for granted and not thought about lest one should trip and fall! Visualisation begins when light from the object perceived (in this case a section of the map), forms a pattern on the retina of the eye. This initial stimulus, which is a 'physical' flow of energy, results eventually in a 'psychological' response. The receptor cells in the retina send signals through the optic nerves which eventually reach the brain. Somehow the brain converts the physical stimuli into meaning. Signals from all the elements in the field are processed so that the map-user can see the features. Despite the simplicity of this description the response is not automatic but it depends on how the brain translates these signals. It is clear, therefore, that the information gleaned from the map is not accepted by the mapworker but is actively processed.

As a 1:50 000 map contains comparatively small and detailed images, detection and discrimination are likely to require foveal (or central) vision, where the detail on the map can only be examined in detail by looking at individual bits of it in a series of movements. The most important movements are the saccadic movements which connect eye fixations (Neisser, 1968). A saccade is a flick from one position to another and it usually takes less than a twentieth of a second. Neisser explains that the optical image is sited on the retina, which contains the terminations of the optic nerve. In the tiny retinal depression known as the fovea the cone nerve endings are clustered. Their organisation and dense packing make possible a high degree of visual acuity.

Foveal vision is described by Neisser (p206) in diagram form, copied over the page:

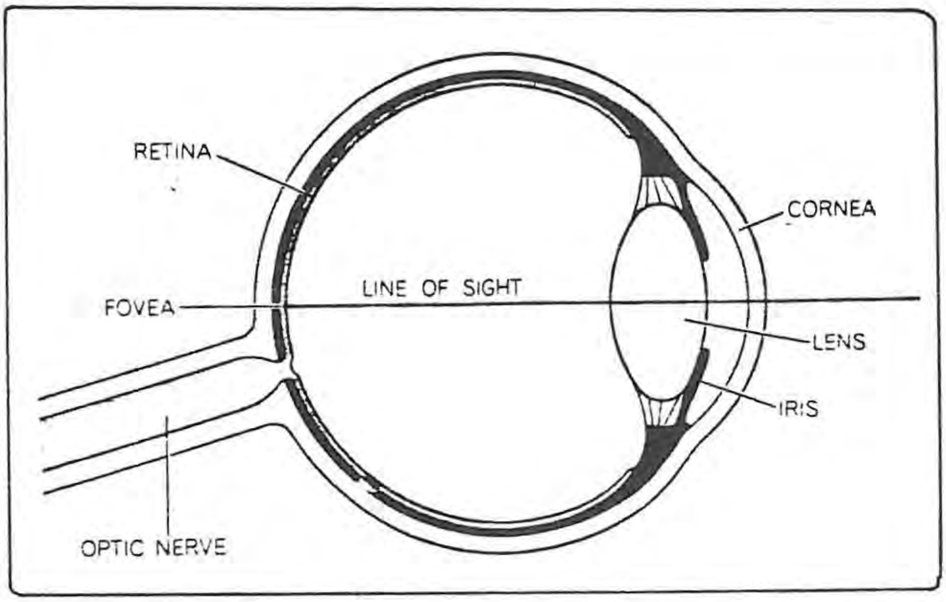


Figure 1.12. Neisser's explanation of foveal vision.

Fixations vary in duration, depending on the complexity of the target and the time taken to perceive it (Castner and Lywood,1978) but generally the eyes will drift away after a few seconds, and will have to be deliberately redirected if the fixation is to be sustained. Ditchburn (1973) points out that a stationary target is never completely fixed in one place on the retina and the effect of this is by no means fully understood.

Blakemore (1977) suggests that information obtained from brief visual storage can pass directly into long term memory, if the experience is sufficiently vivid. This would suggest that a visual image, or some aspect of it, can be stored directly in long-term memory. The connections between vision and memory are clearly important in studying questions of map use.

Keates (1982) analyses the visual processing in the brain and indicates that the primary visual cortex projects into areas of the brain, which are usually known as the visual association areas. Gardner (1979) and Gazzaniga (1972) point out that some evidence for this has been derived from people with brain damage in these areas.

Downs and Stea (1977), proponents for early introduction of contour teaching, focus on neuropsychological evidence and point out that there is this temptation to produce 'maps of the brain', which show the precise physical locations of mental and behavioural abilities. Brain pathology studies warn against oversimplification but these authors make two statements about the purpose and role of the left and right hemisphere structure of the brain. First, each hemisphere appears to dominate the control of a particular set of mental abilities. Second, each hemisphere has its own characteristic way of storing information, handling information and solving problems. What Downs and Stea appear to be saying is that the two hemispheres have distinctive modes of 'thinking', and one can infer that graphicacy implies right-brain thinking. The different left- and right-left brain functions are clearly illustrated with a pertinent cartoon copied below.

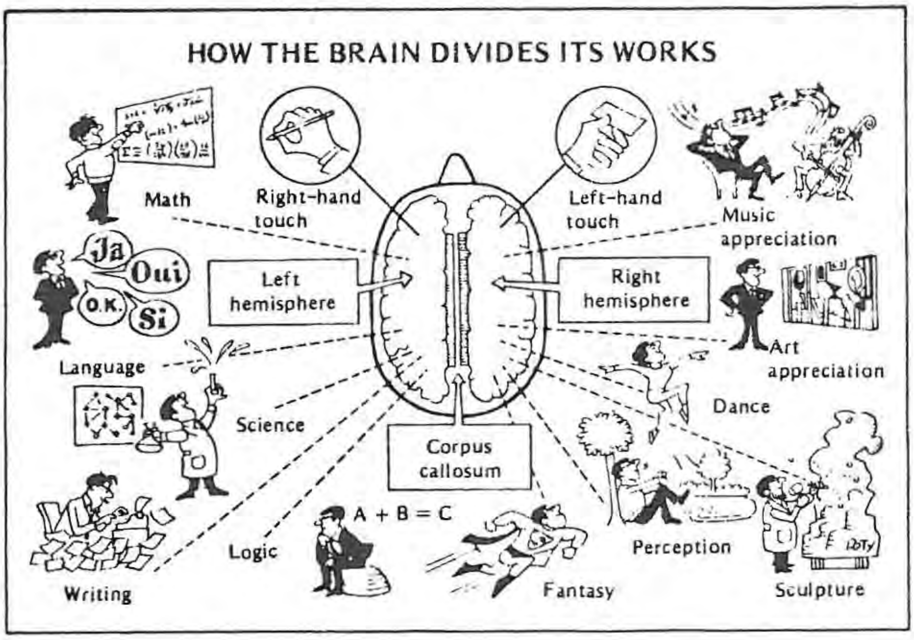


Figure 1.13. A Roy Doty cartoon illustrating the hypothesised division of cognitive functions between the left- and right-hemispheres of the brain.

(Source Downs and Stea, 1977, p.178).

Blake (1979) indicates that recent studies pertaining to right-brain and left-brain functions seem to have important implications for attempts to correct student deficiencies in spatial skills. The right side of the brain accounts for the imagery and intuition that leads people to model and diagram visual-spatial data. Gazzaniga (1972) provides an effective introduction to these differences and about the right hemisphere he notes that the right hemisphere remembers features in terms of a gestalt. This appears to indicate that development of the right-hemisphere is directly beneficial to contour mapwork skill, and that further research in this field may lead the teacher to a better understanding of how and why certain pupils find such difficulty in contour mapwork. It opens a whole new area of research interest. Do people of different cultures and races have different hemisphere dominance characteristics and therefore possess different levels of contour mapwork ability? It is a facinating field but it cannot be pursued within this thesis. Hudson (1958) and Deregowski (1966) have published copious relevant reports in the field and a selected list of their work is listed in the bibliography.

1.3.2. The implications of brain functions for teaching.

Blake (1979) looked into the field and he argued that twentieth century education has been greatly influenced by a technological, linear society that has required teachers to lecture, read, discuss and write logically and sequentially. These are all left-brain processes. He asks, 'has the right-brain become a wasteland through inactivity?' and he points out that students have greater problems with spatial relationships because of the educational emphasis. The conclusion that follows naturally from this line of argument is that maps provide intuitive, visual, image-making, modelling and diagramatic disciplines and one may conclude that mapwork in geography is not only a spatial study but it is also an educational tool to enhance the process of right-brain thinking.

It would appear, therefore, that mapwork, and three-dimensional mapwork in particular has an important educational role to play in the conceptual development in pupils at secondary schools by stimulating neuro-physiological processes.

1.4. VISUAL PERCEPTION.

A percept is made when stimuli received are organised and recognised from a mass of undifferentiated stimuli, when a pattern is seen. The focus of the investigation now shifts to this process.

1.4.1. Visual perception, and the importance of finding embedded shapes, as essential in interpreting contour maps.

Psychological studies of the perception of form and pattern pay a great deal of attention to the recognition of shapes and objects, (Gibson, 1950; Hochberg, 1964; Day 1966; Vernon, 1970; Eliot, 1970; Rock, 1975), and the ideas so developed, in particular those of the school of perceptual psychology known as 'gestalt', are concerned primarily with how people recognise objects by direct perception of the real world.

Keates (1982) analysed the processes involved in mapwork perception and identified detection and discrimination as being central to the first stage of perceptual understanding. The map must have sufficient different stimuli to make them detectable and the symbols must be sufficiently different from one another to allow easy discrimination. Compared with detection discrimination is a complex process and many maps exist in which it is not possible to carry out discrimination with confidence - the slight differences in the symbols or the difference in surroundings of similar symbols (the contour patterns of spurs and valleys) still require the same symbol. An important consideration is that detection and discrimination can be 'learned' and can take place without 'understanding' what the symbols represent.

Keates then further recognized the processes of identification and recognition which imply understanding by the mapworker. Identification of a symbol on the map from the legend would seem to be very straightforward, although different types of identification can be involved in the mapwork task. For comprehension the mapworker has to understand the meaning of the symbols. Keates (1982, p.60) clarifies this point with an illustration. In his own words,

> "Presumably a person can 'read' a completely unknown language by correctly identifying the letters which form the words, but this is hardly what most people would call 'reading'."

It is perhaps how many children attempt to read maps at secondary school. Once the meaning of a symbol is understood, interpretation is possible, and this involves the user's knowledge, and not simply his visual reactions. Clearly interpretation varies with the personal skill and knowledge of the map-user. The distinction between direct perception and the perception of a map is clearly illustrated by the orthophoto map. The orthophoto map combines certain aspects of the map with a transformed photographic image of part of the earth's surface. The patterns of light and dark in the photograph have to be interpreted by the user, so that features in the terrain can be correctly identified, or recognised. Where the photograph image is too ambiguous then cartographic symbols such as contour lines to enhance the three-dimensional view are added (Keates, 1982). On the South African orthophoto map series contours are placed with a vertical interval of five metres and with every 20 metre contour marked with a darker line.

Gibson (1969) drew a lot of attention to the importance of filtering which he referred to as the 'cocktail party phenomena'. This is an area of research interest in the behavioural sciences. The detection task of finding embedded shapes where a target design is camouflaged by a background patterning. The phenomenon is referred to as visual 'noise' and it is clearly an important element in contour mapwork. This relationship was identified as long ago as 1944 by Thurstone and Satterly (1964), twenty years later emphasised the same point in his investigation into the skills and concepts involved in map-reading when he concluded that, the ability to identify land forms on complicated contour maps is dependent upon the ability of the pupils to perceive embedded forms.

Phillips (1979) analysed the processes involved in contour mapwork visualisation and concluded that visualisation itself is a puzzle. He asked what type of visualisation is involved in contour imagery, as it is not a detailed memory of the relief. There is too much information for people to hold much detail in memory. He concluded that when we speak of visualising relief we mean we are structuring our perception of the map in accordance with our understanding of the relief.

The map worker's attention must be selective and the map design must be manipulated accordingly. He must attempt to select what is pertinent without being distracted by the 'noise' of non-related detail. The overall impression given by recent physiological research (Kolers, 1960; Gibson, 1969) is that of a sequence of processes, capable of initially detecting edges, lines and patterns, and subsequently analysing these into more complex structures. Gibson infers that a regular geometrical feature, such as a square, is analysed as an outline consisting of two parallel vertical lines and two parallel horizontal lines. Presumably the analysis of an irregular mapped shape such as the geographical feature, river valley, requires longer and more complex processing, and therefore is more difficult to 'learn'. In this sense, any visual scene or image may be broken down into shapes or patterns, and the brain is then able to operate on them, presumably being able to regroup them as a process of thought.

Because contour shapes and patterns can be ambiguous they can profitably be analysed according to the number of laws of organisation of Gestalt outlined by Hochberg (1964). A fuller understanding of these laws and how they relate to contour map patterns may go part of the way in explaining why some map-readers have more difficulty than others in understanding relief patterns as shown on contour maps.

1.4.2. Seeing the third-dimension from a two-dimensional display.

The psychological studies of form perception investigated for this research thesis have focused on two dimensional aspects and as Eliot (1970, p.277) notes,

> "Literature about spatial perception contains an almost overwhelming number of studies of two-dimensional discrimination. One long-term consequence of this emphasis, however, is that comparatively little is known about the effects of three-dimensional or superimposed stimuli upon children's thought patterns."

King (1985) reinforces this view and his experience is that students of all ages have difficulty in thinking in three dimensions, and he draws this conclusion from evidence in their attempts to visualize the shape of the land from contour maps.

A search of psychological literature (Rock, 1975; Arnheim, 1970; Castner, 1979 ; Gibson, 1950; Hochberg, 1964; Power et al, 1981; Rubin, 1958; White 1973; Vernon, 1970) has led to the conclusion that two widely reported effects may produce perceptual problems in visualizing contour arrays. The array of graphic symbols may imply a widespread psychological reaction in in conflict with the cartographic concept relating slope steepness to contour spacing. The two effects are density or texture gradient effect first suggested by Gibson (1950) and the figure-ground effect originally defined by Rubin (1958). The texture gradient effect is a process which involves the realisation that 'the physical world gets visually denser as it recedes', (Gibson, 1950 p.94). This gradient of density and texture is composed of elements and gaps, and is said to yield the sensation of a continuous third dimension. Additionally, any break in the gradient, with rates of increase identical on either side of the break, will give an impression of a step. Gibson used a number of diagrams with a variety of textured surfaces to emphasise the strength of the gradient effect and some of these have become standard examples in more recent literature for example Neisser (1968 p.204). It is of particular significance to this discussion that diagrams using continuous horizontal lines (Figure 1.14.), variation in line thickness or even a constant line gauge achieves the perception of distance. This raises the possibility that a set of contours may be perceived as a texture gradient rather than as a planimetric representation of altitude changes.

Gibson differentiates between the 'realities' of solid three-dimensional forms, the 'representations' of outline, pictorial and perspective drawings, and the 'abstractions' which are symbolic representations of geometric forms. The three classes are considered to require an increasing degree of concept formation and to be comprehended at progressively later stages in childhood development.

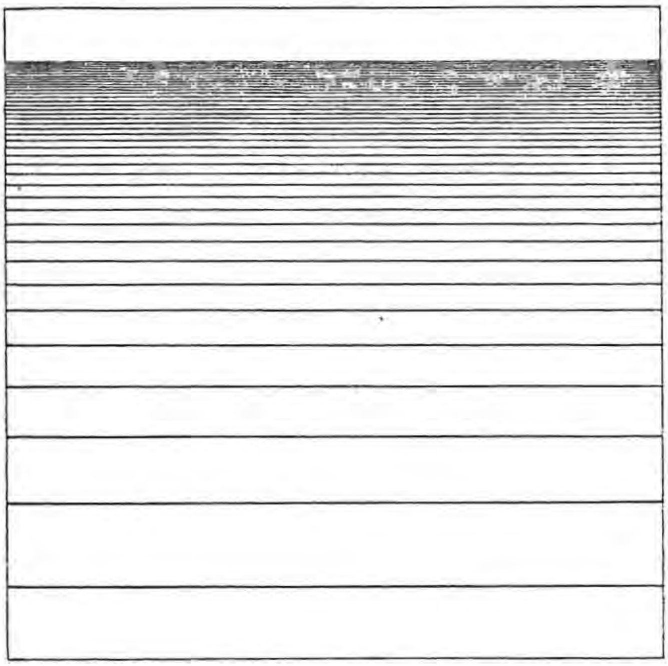


Figure 1.14. Gibson's texture gradient effect with horizontal continuous lines.

Contour displays require a visual perception that is a stage more complex than finding embedded shapes, or the gestalt laws of organisation because contours imply a third dimension. To visualise the real landscape from a contour map the map-reader must not only be able to detect embedded patterns on the map surface but he must then in an abstract manner twist the mental images that he perceives through ninety degrees in his mind. Rock presents the psychologist's view (1975) that the problem of the perception of the third-dimension arises from the observation that the retina can be considered a two-dimensional surface, so that distance per se is not recorded in the retinal image, and he points out that one of the pertinent factors that is worth pursuing is the mental rotation of three-dimensional objects.

Cooper and Shepherd (1984) describe the situation of a dog retrieving a long stick and averting danger when hurtling towards a narrow vertical opening by tilting his head at the last moment and they ask,

> "...and was it not by three-dimensional spatial visualisation rather than by verbal deduction that you, the reader, understood how catastrophe threatened and was averted?"

Psychological experiments were conducted by Shepard with Metzler (1971) and with Cooper (1984) by rotating three-dimensional objects, and the authors claim to have found a way of testing subjective phenomena that was considered outside the scope of experimental psychology. But not much is known and questions remain unanswered about the nature of the mental transformations involved.

Lappan, Phillips and Winter (1984) reported on the importance of improving the perception of three-dimensional spatial relationships in mathematics. This is because most of a student's mathematical experience with the three-dimensional world is obtained from two-dimensional pictures. Yet the authors claim that many students cannot 'read' these two-dimensional pictures well enough to determine needed information about the solid objects. They recommend that teaching programs should support the full range of problem solving in mathematics (the use of imagery, visualisation and spatial concepts) and that there should be emphasis on using concrete representations that aid the perception of spatial relationships. These recommendations pinpoint the value of the use of models in contour mapwork.

Satterly (1964) was a proponent of the view that perceptual ability is a major factor underlying certain aspects of mapwork and therefore he concluded that a teaching programme designed to increase perceptual skills should be devised and that this would in turn improve mapwork skills.

Perhaps more than anywhere else, further research into the perception of three-dimensional forms from two-dimensional planes will help teachers to introduce the skills of contour mapwork effectively.

1.5. THEORIES OF CONCEPT DEVELOPMENT RELATED TO RELIEF MAPWORK SKILLS.

The focus is now drawn to the pupil and his/her stage of intellectual development. It involves a consideration of relevant aspects of theories forwarded by Piaget and Bruner and Rhys's application of these theories.

1.5.1. Jean Piaget's sequential conceptual development theory.

According to Piaget's scheme of things, a child passes through four stages of development - these are the sensorimotor, pre-operational, concrete operational, and formal operational stages. The stages that largely concern the teaching of mapwork would be the last two. A brief summary of Piaget's research (Hart and Moore, 1973) reveals that the understanding of spatial concepts proceeds in a series of stages as a child advances from a state of egocentrism to one where it able to abstract. Stages of development take place in a sequence which is stable and every child must pass through the same stages. These are summarised in Table 1. over the page.

Table 1.1. Piaget's model of mental development.

TABLE 1.1. PIAGET'S MODEL OF MENTAL DEVELOPMENT
Adapted from Beard (1969), Graves (1975), and Welch (1981)

SENSORIMOTOR PERIOD	CONCRETE OPERATIONS PERIOD				FORMAL OPERATIONS PERIOD
0 - 18 mnths	Pre-conceptual substage 18 months - 4,5 years.	Intuitive substage 4,5 to 7 years	Concrete operations substage 7 - 12 years		12 years +
Begins to know immediate environment, factually and visually	Beginning of symbolic representation: words, actions, drawing, writing. Not able to form concepts - is inconsistent.	Simple descriptive concepts based on experience of environment. Difficult to review a situation mentally - needs the object of discussion present. Thinking is ego-centric - difficult to conceive of a situation in which they are not involved. Difficult to under-stand relationship between the part and the whole. Experience difficulty with relative terms.	Can manage more complex concepts and learn to deal with concept hierarchy. Can review a situation mentally. Able to arrange data according to size. Can grasp symmetrical relationships. Classify things according to two or more criteria.	Difficulty in arguing from verbal propositions. Tend to reject a premise which seems to contradict their experience -Cannot easily conceive of an hypo-thetical situation. Does not understand the meaning of general laws. -Cannot explain in terms of a general principle, theory or law. Cannot easily give verbal definitions - difficulty in explaining what "the general case" is.	Able to think in a hypothetico-deductive manner. Problems may be solved by internal processes of thinking and physical experi-ment, rather than by trial and error. Inductive thinking - regularities or laws may be inferred from evidence provided. Becomes aware of need for, and importance of precision in defining concepts in terms of attributes as a class of objects or ideas. Can conceive mentally of "relations between relations" - multi-variate situations.

It is the formal operational stage that is of great importance to the secondary school teacher of geography since it covers the range of twelve years onwards. At this stage pupils are able to manipulate in their minds objects that are not physically present. Boardman (1983) sums up this fundamental point with the phrase '... the real versus the possible'. The formal thinker proceeds by considering all of the possible relations implied by the data or information and then by attempting logical analysis to make a judgement. Ruth Beard (1969) succinctly summarises the capacities of the teenaged formal thinker, and the following list is based on her summary, some items being quoted directly. The student at the stage of formal operations can :

(a) accept assumptions for the sake of argument;

(b) make a succession of hypotheses which he is able to express in propositions and to test against reality;

(c) begin to look for general properties which enable him to give exhaustive definitions, to state general laws and to see common meanings in proverbs or other verbal material;

(d) go beyond the tangible, finite and familiar in spatial concepts, to conceive the infinitely small and to invent imaginary systems;

(e) become conscious of his own thinking, reflecting on it to provide logical justifications for judgements he makes;

(f) deal with a wide variety of complex relations such as proportionality or correlation.

For the teacher, the main implications of this list must be that if these are the operations which develop in children from eleven-and-a-half to twelve years, then, before they have reached this stage there are obvious limitatations on the forms of mental activity of which they are capable. It is an important point for teachers to realise that there will be great differences between children of the same chronological age where their mental development is concerned. The theory needs to be accepted as a framework for the understanding of the development of thinking, rather than as a rigid prescription.

Several aspects of Piaget's theory must be considered as central to an understanding of his position. First there is the idea that children differ from adults not only quantitatively in their cognition, but qualitatively as well. That is, they are not cognitive miniatures of adults, but they think in their own way. Second there is the notion of stages (or periods). The stages are an ordered series. This means that while the ages associated with a specific stage are variable, the sequence of stages is invariant and immutable in Piaget's system. Third, the stages are connected by a mechanism of development and change. The mechanism is based upon two functional invariants, two ever-present processes. The first process, assimilation, refers to the attempt to incorporate new and different experience into existing cognitive structures. Assimilation is "... the integration of any sort of reality into a structure" (Piaget, 1972). Accommodation involves the readjustment of these cognitive structures to try and cope with more of the real external world. Assimilation and accommodation work simultaneously, and development demands a progressive coordination of the two. It is this process of coordination, called equilibration, that underlies cognitive development in the child.

Piaget stresses the active exploration by the child of his own environment as of key significance in cognitive growth and this would appear to be a useful pointer to teachers who introduce contours by using the home environment. Through assimilation and accommodation, experiences are organised into schemata, which are patterns of knowing.

Graves (1975) points out that much of the evidence that has accumulated since the 1950's suggests that many adolescents and adults go on thinking in concrete terms for many years, particularly when faced with a novel or unusual situation. Despite this and other criticisms (Bady, 1978), the many replications and further experiments based on Piaget's theories have proved that there is no doubt that very significant implications for teaching and learning have arisen from his work. Driver (1978) is also quick to point out that many initially sceptical researches have found that Piaget's experiments have given repeatable results.

1.5.2. The developmental psychology of Jerome Bruner.

In contrast with Piaget, Bruner's view of cognitive development is not as rigid or as strictly tied to developmental stages. Bruner (1960) summarised his view as 'any subject can be taught effectively in some intellectually honest way to any child at any stage of development'.

Bruner's theory of concept development differs from that of Piaget's in that he opposes the notion that rigid states of development occur at specific ages. Although Bruner's theory has areas of agreement with Piaget's, one basic difference emerges - it is the way in which each views the age at which different thought processes can occur. Bruner emphasised the value of helping learners to understand the conceptual structure of the subject, suggesting that this structure is so basic that some level of understanding may be achieved at any stage. His theory, therefore, stresses the environmental factor in development rather than the maturational one. Bruner's theory leads one to the conclusion that concept development can be speeded up if learning situations are manipulated. Bruner is concerned to describe how a child represents the world, and he suggests that a child begins with an active stage of representation, which he calls the enactive stage: "... the child's world is known to him, principally by the habitual actions he uses for coping with it." (Bruner, 1966)

This enactive period described by Bruner parallels Piaget's sensorimotor and concrete stages of development. Bruner's child then moves through the iconic stage of representation which occurs with the development of a relatively free from action imagery to a symbolic representation where the child translates action and image into language. The three modes of representation work together to form concepts.

Graves (1980) points out that although teenaged students may have passed through all three stages, they may still use enactive or iconic modes when appropriate. The major idea that has emanated from Bruner's writings, which affects the teaching of mapwork in geography, is the part which instruction plays in the process of concept development. Whereas teaching strategy based on Piaget's theory could be termed passive in that it moulds itself around the thought processes of the child, Bruner's is active as it endeavours to speed up the process of concept formation. Bruner's view is that concepts need to be revisited by pupils a few times as they progress through the school. This contention has led to the adoption of a spiral curriculum plan in which the central concepts are developed and refined year by year.

1.5.3. Implications of developmental theories.

Graves (1970) asks if it is possible to arrange the content of geography in such a way that some sequential learning takes place from the simpler to the more complex ideas and skills. Blaut (1974) and Downs and Stea (1977) reply that early environmental learning may constitute a prototype experience for the learning of non-dimensional language. It provides the necessary 'template' for the acquisition, achievement, or attainment of the ability to understand written language. A structured and sequential teaching programme related to conceptual development theory would perhaps provide an answer to the problem of poor pupil performance that is so frequently reported (Ballantyne, 1984).

Barton (1964) took a pessimistic view and claimed that,

"It is impossible to design a precise numbered sequence for developing geography skills because as yet insufficient evidence has been collected by research in the behavioural sciences, experimental teaching, diagnostic testing, and other kinds of research. All that is available today are some suppositions as to what is or what is not too difficult for various groupings, and some suggestions concerning a sequence of techniques based on the limited observations, logic, and judgement."

1.5.4. Rhys's geographical application of developmental theories

Rhys (1972) in an investigation into the development of logical thinking pointed to the work, starting in the 1920's by Piaget and his associates seeking to analyse the intellectual techniques and logical processes employed by children at various stages of their growth concluded that relatively few enquiries have been concerned with children's conceptual growth in geography. He set up an experimental investigation in order to ascertain the quality of judgement that could be obtained from pupils at successive levels of understanding.
Rhys presented his results in Table form copied below,

Group	Age	Mental Age	Principal features
I	11.0 and below	12.0 and below	Not reality orientated
II	12 to 12.6	13 to 13.6	Reality orientated; single piece of evidence used
III	circa 13.6	14 to 14.6	Several pieces of evidence combined; able to relate cause cause and effect
IV	14.6 and above	15.6 and above	Comprehensive judgement based upon upon hypothetico-deductive reasoning

Table 1.2. Results of Rhys's experiment of testing developmental logical thinking.

His findings suggest that because a child under the mental age of twelve is not reality orientated contour mapwork would best be introduced after this age and that only very simple concepts should be considered before the age of fifteen and a half and above. Rhys confirms this view and concludes that limitations imposed by concrete-operational thought are gradually removed during the ages twelve to fifteen when the adolescent develops an ability to make use of propositional operations within a conceptual system which can be equated with a self contained 'structure whole' (Inhelder and Piaget, 1958) Rhys concluded that the interpretation and explanation of the symbolised material could only take place at the conceptual level, making use of those cognitive structures which link the individual's present perception and learning to his previous experience. The experimental investigations of Piaget and Inhelder (1958) into the powers of reasoning employed by children at different levels, have shown that the ability to deal with problems involving several elements or variables does not arise until past the age of twelve.

Rhys strongly supports the contention of Peel (1968) that a gradual transition may be discerned during adolescence, with the largely descriptive form of thought, which is used at first, giving way to a comprehensive, detailed and fully adequate power of explanation. Rhys claims that the extent to which intellectual progress can be accelerated has yet to be clearly established. His final conclusion is worthy of careful note,

> "It remains true, however, that even the most enlightened teaching will be of little avail unless the child is in possession of those structures of thought which will allow him to absorb the material provided and profit from the experience."

Rhys's experiments with a sample of secondary school children using geographical materials show that, when set a problem in which they have to disentangle various factors and arrive at a logical solution, given the evidence, the average age at which logical thinking can be said to begin is fourteen years.

1.5.5. Developmental theory, a summary comment.

It is clear that the nature of geographic work in schools relates to current insights into how pupils learn. Learning is a highly individual process and, although teaching is done to groups, it is the individual who learns. Individual differences, therefore, need to be taken into consideration in learning situations. Children at different stages of cognitive development differ in their learning needs and interests. Educational and psychological research has focused on the way that a child comes to understand his world. The works of Piaget and Bruner have been fundamental in their influence, Piaget in his research findings and Bruner in the way he has applied these findings to curriculum structures. Piaget suggests that for 5-13-year olds education involves the use of the child's own experiences that have happened in the immediate local environment. Bruner suggested a problem solving approach rather than didactic and verbal teaching. Bruner's envisaged spiral curriculum suggests that certain key concepts, ideas or generalisations are revisited at increasing levels of complexity as the child matures. Only by isolating key ideas, and organising the learning experiences such that increasing sophistication is introduced, does Bruner consider a teaching programme will suit the thought patterns of the child, so that he can cope.

The next section deals with some research into the teaching of mapwork skills so as to ascertain how pertinent Piaget's and Bruner's hypotheses are. The focus at the research level is on poor performance, as difficulties have long been recognised although Satterly (1964) points out that it is too often assumed that there is nothing to teach in mapwork; maps are merely an adjunct to class lessons 'something to wave a hand at'.

1.6. MAPWORK SKILLS : SOME KEY RESEARCH REPORTS.

Attention is now focused on the transaction of teaching/learning contour mapwork. First the problem of poor learner performance is emphasised with more detailed consideration given to selected pertinent findings.

1.6.1. The problem of poor performance.

Bartz (1970) reveals the problem with clarity,

> "Educators say that they value maps and mapping, but the evidence of children's peformance in using maps is contradictory. While a great deal of value is apparently placed on teaching about maps and with maps in professional journals, in how-to books, and in official curriculum outlines, in fact, the objectives are not being met".

Certain selected research investigations into this dilemma are now reported.

1.6.2. The Training College Committeee of the Geographical Association (1941)

One of the earliest studies was motivated by the Training College Group Committee of the Geographical Association after tentatively investigating (1937) how far children learning geography form true conceptions of much of the data presented to them. As a result of the preliminary tests, the Committee attempted a full-scale investigation (1941) to attempt to discover how far children can interpret the actual forms presented by contour lines in terms of a simple landscape.

They tested nearly 40 000 children aged 8 to 17 in Britain by setting two exercises. These asked pupils :

1. to say which out of four maps corresponded with a given picture, and
2. to say which out of four pictures corresponded with a given map.

The maps were cut off at the limit of vision and the direction of viewing was indicated by an arrow. The contours were not numbered on the maps. The investigators presented their results in a series of graphs which showed :

1. there was a steady rise in ability in boys and girls from 10 to 15 to relate solid form to contour symbolism,

2. boys from 11 to 15 and girls 13 to 15 showed a greater facility in relating a map to one of four pictures than a picture to one of the four maps,

3. the graphs showed an obvious break at the age of 10 years and that regular progress does not begin until after this age.

4. Girls did better than boys up to the age of 12 and 11 in the two exercises respectively.

5. Children who had used Ordnance Survey maps in the field did better than those who had only used them in the classroom.

Other interesting results claimed by the Committee include a close correlation between performance and intelligence; boys in boys' schools and girls in girls' schools did better than mixed schools; there was no difference between rural and urban schools; and children who lived in hilly regions followed the norm. The Committee concluded that boys and girls can interpret shape correctly from contour lines more often, and at younger age, than is commonly supposed. Experience with O.S. maps improved performance, "but it is a capacity that may exist without any specific teaching." They pointed out that the investigation showed a need for further experiments, especially in connection with the abilities of the younger children.

Since this report there have been several studies investigating the problem of poor performance by children in map reading exercises. One particularly significant piece of research in the field was conducted by Satterly (1964), who noted an inability to visualize solid reality from contours on a map by 60 fourth form secondary school pupils aged 14 to 15 plus in Bristol.

1.6.3. Satterly (1965).

Satterly administered a series of tests which were divided into two broad groups. Psychological variables made up the first part of the test. It had three parts :

A. Conceptual

B. Spatial skill

C. Perceptual - with particular emphasis on embedded shapes and on speed.

Tests of mapwork performance made up the second part of the test. The seven skills tested included map drawing, recognising conventional signs, contour representation of land forms when discrete, contours in a complicated contour organisation, use of the national grid, orientation and settlement identification.

From these tests Satterly intercorrelated the psychological variables and the mapwork performance tests and found them to be significant statistically at the one per cent level of confidence. So as to test how far mapwork ability could be predicted from the psychological tests, one map test was submitted for a multiple regression analysis and the result of this was that the test for embedded shapes was the best single predictor.

Satterly's conclusion was that perceptual ability is a major factor underlying certain aspects of mapwork and he therefore suggested that a teaching programme designed to increase perceptual skills should be devised.

1.6.4. Boardman and Towner (1979).

They investigated some of the problems that were encountered by older pupils in reading contour maps and interpreting three-dimensional aspects of topographical maps. The sample analysed was a big one consisting of 578 fifth form students age 15 to 16 in twelve Birmingham schools The pupils were divided into three groups :

-following O-level courses	(209)
-following CSE mode 1 course	(203)
-following GYSL Project	(166)

Boardman and Towner devised a test covering a range of map reading skills divided into four sections. One of these sections was to test the pupils' understanding of relief. It dealt with visualization of three-dimensional landscape from a two-dimensional map. Questions on height and slope were asked. Two tests were applied :

Test 1. A contour map was provided and the pupils were asked to shade areas below a certain altitude.

Test 2. Four short lines placed on the contour map were used to test understanding of slope. The first was a simple task of indicating which end of each line was higher, then the pupils had to assess which of the four lines lay on the steepest slope, and finally the pupils had to identify three points on the map and indicate which was the highest.

The results of the contour shading test showed that just under half of all the candidates obtained full marks and a range of success was shown between O-level pupils (80%) and GYSL pupils (17%). In the slope assessment tests the same ranges became apparent. Indicating which end of the lines was higher than the other was more successfully completed by the O-level pupils (92%) than CSE pupils (81%) and GYSL pupils (61%). Assessing which line lay on the steepest slope was answered wrongly by more pupils in each group O-level pupils (77%) selected correctly, CSE pupils (49%) and GYSL pupils (31%) correct. In height estimation only (68%) of the O-level pupils answered correctly, only (29%) of CSE pupils and only (16%) of the GYSL pupils.

One may conclude that the erroneous ideas exposed by Boardman and Towner's test are worthy of further testing. In contour shading some pupils stopped shading below the next contour down thereby failing to realize a continual fall of land. That half had an incomplete understanding of what a contour map represents was a serious pointer for further investigation. Steepness of slope gauged by closeness of contours was not fully understood and height estimation showed another serious weakness.

1.6.5. Boardman (1982).

Boardman revealed further erroneous ideas about relief in a research exercise where he tested 166 pupils aged 11 to 12, and 170 aged 13 to 14 from six schools in the West Midlands of England. In this test the pupils performed the same tasks as in Boardman and Towner's earlier (1979) study but on a much easier contour map. The results showed that similar errors were made to the earlier study and this time the scores of the younger group were worse than those of the older children. Boardman concluded that understanding of relief as shown on contour maps develops steadily with age but is still incomplete by many pupils by the time they leave school.

1.6.6. Griffin and Lock (1979).

An important research study in this field was conducted by Griffin and Lock (1979). They investigated the problem that map-users often fail to obtain an accurate visual image of relief forms from contour maps, and they claimed that little is known about the specific problems that they experienced. Griffin and Lock tested a substantial sample of 701 Australian subjects - 4 Adelaide schools provided 484 subjects (they were members of sixteen geography classes for years 10,11 and 12) and at the tertiary level 217 general degree students from the University of Adelaide Department of Geography participated. A multi-choice questionnaire was given that concentrated upon the ability to identify different types of slope on contour diagrams. The test procedure required subjects to compare contour diagrams with both profiles (20 questions), and block diagrams (8 questions) in the context of a multiple-choice questionnaire. The strategy of the test aimed at requiring the subjects to make responses that could act as a measure of the extent to which their interpretation of contour patterns was erroneous, and it was completed during 27 sessions, there were no time constraints.

They found that in general, there was an improvement in performance with increasing educational experience. Slope reversal errors proved to be not only prevalent but also extremely persistent, even among the most able and most experienced subjects. In general it appears logical to suggest that a considerable part of the erroneous interpretation evident amongst test subjects was due to a lack of conceptual competence. Conceptual difficulty existed, but the failure to judge the relative steepness of slope was explained by recourse to perceptual error. It was concluded that this may be related to Gibson's texture gradient effect.

1.6.7. Phillips, de Lucia and Skelton (1975)

Phillips, de Lucia, and Skelton tested the legibility of four different types of relief map. To do this they tested 179 police cadets aged between 16 and 18 years, divided into two groups according to past map reading experience. Thirteen different questions were administered to subjects for each of four types of map. The four map types were digits, contours, shading and tints.

The questions involved highest and lowest points, higher end of a line, height estimation, locate town names, river, higher end of a line (map upside down), draw around areas over 200 feet, intervisibility, locate steepest slope, matching profiles, find the nearest towns, shortest routes, model questions.

The significant results of their tests relating to the third dimension showed that, "contour maps were clearly difficult to use, perhaps because it is not always easy to discover which side of a contour line is the higher one." The tests showed that those who were tested with contour maps did not do particularly well on any of the questions, even though many of the subjects had considerable experience in reading this type of map. However, for some purposes, they were the best compromise between the very visual tint maps and the very quantitative digital maps.

1.6.8. Phillips (1979)

Because of the problem of poor achievement in contour mapwork Phillips considered methods of improving contour displays to improve interpretation performance. To test these methods Phillips gave a questionnaire to 88 geography undergraduates in two university departments in London and it was apparent that only 8 could successfully read altitude with altered label orientation. Then he set a similar task to 103 undergraduates but found no significant difference between the two groups. In a third experiment Phillips attempted to train geography undergraduates to make use of the orientation label but no improvement was noticed. He decided that, "whatever the reason, it is clear that the orientation of the contour label is not helpful to experienced map readers".

Phillips then tested university undergraduates (59 men and 28 women) aged between 18 and 46 (median 20). This time each subject received a booklet with contour maps and wedding cake contours. They were required to ring the higher end of short lines, and to assess the highest and lowest points on the maps. Time was controlled. It is interesting to note that he found that differences in performance between the contour and wedding cake methods failed to reach statistically significant levels. This seemed to prove that there is no advantage in using wedding cake maps as a possible improvement on the contour method.

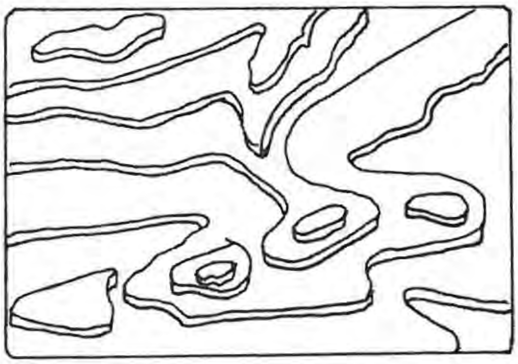


Figure 1.5. Phillips's 'wedding cake' contour method.

1.6.9. Underwood (1983).

In a more recent study, Underwood tested two causes of the failure of map users to successfully interpret relief forms from contour maps. He listed these as Gibson's texture gradients effect (which may give false depth cues) and the expectancy, or prior set developed from previous experience by the map reader.

For his first experiment, Underwood tested 53 first year undergraduates who were studying a range of courses at the University of Waterloo, Canada. The subjects were presented with individual booklets which had a short descriptive passage and instruction, and ten contour patterns. The contours were not numbered. The subjects were randomly divided into two approximately equal number groups, each with a different passage :

Group A's passage described a descent from the Pyrenees to the Meseta Plateau.

Group B's passage described a journey up to the central plateaux of Asia. The subjects then read their passages and had to draw cross-sections from their un-numbered contour transects.

Underwood concluded from this experiment that most of the subjects in the two groups were already heavily biased towards equating high land with steep land. He then tested forty-three 13th Grade (18-year olds) high school subjects studying a range of subjects including geography in the final term at Waterloo Collegiate.

He employed the same ten simplified contour patterns that he had used in his first experiment but below each pattern was drawn two alternative but valid interpretations. Other interpretations of the contour patterns were not admissable. This time the subjects equated high with steep despite being made aware of other interpretations. Underwood then refined his study and tested 23 first-year undergraduates, whose modular degree included geography, by only presenting six contour patterns to the subjects, and each pattern was accompanied by four possible cross sections. He claimed from this experiment that the subjects were able to equate steep and low, which suggested that the failure by the earlier group was a reflection of the limited choice of sections available to them.

Underwood concluded that, 'in summary it is suggested that expectancy is the dominant influence on contour interpretation'.

A review of research literature has indicated that important answers are being revealed that may help to solve the problems of poor performance in contour mapwork. Educators must pay careful attention to the findings of workers in the fields of cartography, neurophysiology, perception and conceptual development theory and apply these findings to a more carefully structured teaching programme.

The present state of affairs in South African schools is investigated in the next chapter and special attention is focused on the problems to be found.

CHAPTER 2

THE TEACHING OF RELIEF MAPWORK IN SOUTH AFRICAN SECONDARY SCHOOLS

2.1. INTRODUCTION

The teacher attempts to transmit mapwork concepts to pupils but most of the sources investigated indicate that there are major problems in this transaction.

> "I suspect that there is a gross oversimplification in the minds of teachers of just what is involved with reading a map. After all, a map is an extremely complicated combination of lines, colours and symbols, in which reality has been transformed in terms of scale, shape and perspective. I suspect that wrong things are being taught about maps." (Carswell 1971)

The Handbook for Geography Teachers, (1974, p.191) hones the problem to a sharper focus on three-dimensional graphicacy,

"The most difficult symbol on the map is undoubtedly the contour line. It cannot be seen in the field but must be imagined as following a line of zero slope."

This chapter draws attention to how three-dimensional graphicacy is taught in South African Secondary Schools. It examines texts and articles directed to teachers and then focuses on the examination syllabuses, the text-books available in South Africa and some comparative overseas examples, reviews selected past examination questions and concludes with a teacher questionnaire devised to test the views of certain teachers.

2.2. RELIEF MAPWORK IN TEACHER EDUCATION TEXTS AND ARTICLES.

An early manual used in teacher education, by Wallis (1921) indicates that teacher guides have been available for some time. The method suggested to introduce contour work is to start with early pictorial forms of showing relief. The next step is 'largely outdoor work' where the author suggests arranging pupils on a slope 'so that their feet are at the same level' or noting lines along the bank of a stream. Indoor methods of arriving at the appreciation of contours include sand trays and clay or plasticine models. These are to be made by the pupils and then equal level points joined up with lines. The edges of models, usually sufficiently well-cut, can be used to introduce profiles. Other practical suggestions include drawing outline contour maps, sketched contours, panoramic pictures, as this lies in the ability of the pupil to make a drawing represents the configuration of the district as he imagines it.

Wallis (1921, p.150) concluded his chapter on contour mapwork with the perceptive view that,

> "No illustration of a discussion of the relief of any area can be regarded as adequate unless there be some attempt to indicate three dimensions and illustrations should appeal to the eye as as well as imagination".

These views are pertinent to today's teachers sixty-five years on and can be seen reflected in the recommendations outlined in Chapter 4.

Fairgrieve (1926) suggested a novel introduction to contour work shown diagramatically below,

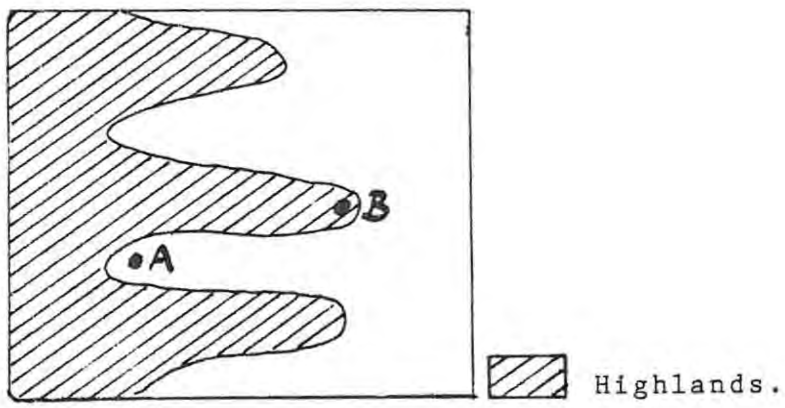


Figure 2.1. Fairgrieve's diagram to introduce contours.

Highlands are shaded and lower land left unshaded to show ridges and valleys and this boundary line is the 'germ' out of which the contour line may be developed. The next step that he advocates is to consider a lake, noting that any Fifth Standard or Lower Fourth boy can at once tell how the depth of a lake may be found by dropping a string with a weight at the end until the weight touches the bottom. In this way a series of points is recorded, but Fairgrieve warns, that the fact that the relationship of these points requires careful teaching emphasises the fundamental difficulty of grasping the idea of a line. Another novel approach suggested by the author is to use the window of the classroom to draw a profile of any visible landform on the glass and this is eventually translated onto the page.

It is interesting to note that fifty years ago these authors were advocating practical approaches to the introduction of relief mapwork and that the order should be from known towards unknown. In 1939 the Association of Assistant Masters in Secondary Schools in Britain published the Memorandum on the Teaching of Geography. In a chapter on teaching methods contour map-reading is considered in a series of numbered paragraphs. The teachers noted that the teaching of contour-map reading is one of the most difficult problems that the teacher has to face. It was claimed (p.174) that "there can be little doubt that the first approach to contour map reading should be through out-door work", and they too, advocated lining up pupils' feet along a slope. This should be followed by modelling particularly with models that can hold water and thereby allow water levels and lines to be ascertained. The authors first drew attention to the potential value and opportunities provided by the newly developing aerial photography techniques. They then suggested working from spot heights, interpolation and then towards contour map reading but the warning they make is clear and very pertinent still. "It is essential that the meaning of contours should be known before any attempt is made to use contour maps" (p.177)

Garnett (1960) advocates introducing contouring to young children, as she claims that an early start by colouring large-scale layer maps leads to a 'surprisingly sound grasp of contouring'. From this simple start development must be from 'stage to stage'. The principle that she suggests is, that the approach should be direct. Garnett noted that most British texts of her time introduced contours with reference to a model but her warning is that if real landscape, and favourably familiar landscape, is not studied, 'the children will begin to visualize relief models rather than realities when reading a map'. The step from reality to abstraction is considered to be best done by interpolation exercises but unknown or imaginery landscape should only be considered after contouring of a familiar area has been carried out by the children. Garnett also considers contouring of depths below water to have value as an approach.

Most recently Boardman (1983) has published a valuable text Graphicacy and Geography Teaching with the fourth chapter 'The Third Dimension' devoted to teaching this field of mapwork. Unfortunately the term 'graphicacy' is new and teachers are not likely to be attracted to use the guide. It does, however, offer many useful pointers. Boardman, like the earlier authors, claims that, "... the concept of contours should always be taught with the aid of models when children are still at the stage of concrete operational thinking." He motivates this claim by stating, "It is difficult enough for children to think and visualize in three-dimensional space, but it is even more difficult for them to do so when they can only see three-dimensional ideas represented in a distorted two-dimensional manner on paper."

He outlines many useful pointers for constructing landscape models for contouring, and he advocates the use of a containing tank but adds that some thick acetate can be employed at the top of the tank to trace lines upon from an above view. Boardman stresses that correct terminology must be used so that pupils see that a contour is a line drawn on a map and that contours do not appear on the ground.

Boardman points to the value of landscape sketching as a skill to be used to introduce an understanding of the third dimension of the landscape and also a method of recording this on paper.

The New Unesco Source Book for Geography Teaching outlines a teaching strategy of individualized learning to introduce contours. A series of frames prepared by Okunrotifa (1974) is displayed through twenty three pages as an example of programmed learning employed in Nigeria among 12 to 13 year old pupils. The drawbacks of this method appear to be the huge time consumption necessary in constructing the frames and the distance from reality that they present. They are each abstract exercises but they do have the value of being personal, individual learning exercises.

Hurry (1978), has produced the best South African teacher's guide and he offers some novel methods of contour modelling. He too emphasises the value of using models by pointing out that, 'the pupils are learning about their environment, and this environment has depth as well as length and breadth.'

So far this review has focused on book publications, but the alert teacher will find valuable material in journals as these too have focused from time to time on the teacher's dilemma of how to teach the difficult three-dimensional graphicacy concepts involved in contour mapping. The focus will now shift to some of the more useful guides found in articles in journals. The search has been restricted to articles since the 1940's, even though there are valuable references before this time, because of the pressures of time and space.

David provided help in The Teaching of Contours in Geography (1944). She too noted that the study must in its early stages be, "... based on experience and impressions gained within the local region". An important warning with which she introduces her paper is, "whatever the method employed, the treatment must be geographical rather than mathematical and there must be pictorial aids." David then offered five model lessons to be presented to pupils entering Senior school. The lessons followed this order :

Lesson 1. By means of photographs and pictures to interest children in the relief of the land. To establish a connection between the picture and the map.

Lesson 2. To make a contoured sketch map of a local hill, with the aid of pictures and model.

Lesson 3. To examine a contoured map of a local river valley.

Lesson 4. To interpret the main features of relief as shown on a 1" O.S. Map by means of an imaginary cycle tour in the Lake District.

Lesson 5. To introduce specifically some of the terms used to describe different slopes. The drawing of contour map from a written description.

The Stellenbosch based Journal for Geography provided Some Hints on Teaching the Representation of Relief by a schoolteacher, van der Spuy (1966). He advocates a very delayed approach and suggested that contour mapwork should be introduced in 'relatively late in the Std. 10 year.' Even then he suggests a start with the local area as the base. Van der Spuy lists nineteen points or guides, more for a final matriculation candidate, than for a teacher introducing graphicacy skills but it is nevertheless a useful list of experiences that a practicing teacher shares with other geographers. It includes problems of time, importance of reviewing past papers and some study procedures. He finishes by noting, "... one can spend a term on this section without wasting any time!"

Recently, the teacher-orientated British magazine, Teaching Geography has highlighted some 'bright ideas' as a special section of interest. The first relevant article, (King, 1982) attracts attention with its title, 3D into 2D - Teaching Contours Using an Overhead Projector. It outlines how a simple model can be constructed with clear acetate so as to display its reality and to allow light to pass through it onto a screen to display contour patterns. It is a very simple but ingenious method of rotating a model so as to display profile, overhead view and three-dimensional structure. Munowenyu (1985) stimulated by this article was prompted to suggest a method of using polystyrene to model as 'another bright idea'. Another immensely practical suggestion offered by this section of the journal by Sutcliffe (1983) describes how a hexagonal 'peg-board' can be constructed to form a three-dimensional template with which to make relief models.

One of the most popular publications in South African secondary schools is The South African Landscape by Liebenberg,et al (1980). It is an exercise manual for map and photo interpretation and its value lies in the fact that it contains 76 map extracts in an easily manageable ring-back binding. This highlights a major problem that secondary school teachers face when teaching mapwork; the difficulty of finding convenient-size resource material. 1:50 000 Maps of the South African series measure 53 cm x 76 cm which makes them very unwieldy and cumbersome for normal school desk manipulation. This book, therefore, with A-4 size map extracts is very handy and can be used in a variety of pertinent map-study exercises. They are pertinent because the extracts are representative of a variety of South African landscapes, so that map-reading exercises can reflect landscape coursework learning. Its one major weakness is that lines of latitude and longitude are left off and this is frustrating to teachers who wish to pinpoint features.

Liebenberg's manual reflects the very useful British series edited by Edwards, British Landscape Through Maps (1971). It is a series of thirteen booklets which interpret through maps the development of the great variety of British landscapes. At the intermediate level Robinson and Wallwork (1970) analyse eleven areas in detail as sample studies. Where Libenberg's book is better than the British texts is that the South African book contains actual 1:50 000 topographical maps whereas the British books refer to maps that can be viewed elsewhere.

Another avenue that the teacher may explore is the avenue of games or simulation. One text in particular serves to illustrate this approach. Maps and Map Games (Manley, 1976) is loaded with ideas on how to introduce serious relief mapwork concepts with a 'fun' method. It is certainly not a frivolous approach but one that many teachers might get benefit in exploring, as a lively foil to the somewhat diffident examination-orientated approach of South African Texts to be reviewed later in this chapter.

2.3. THREE-DIMENSIONAL MAPWORK IN THE SOUTH AFRICAN SCHOOL SYLLABUSES.

The new syllabus for matriculation geography introduced in 1979, suggested a start to three-dimensional graphicacy in Standard 8 and suggested contour sketches and drawing topographic profiles as suitable for this level. Identification and interpretation of landforms was deferred to the Standard 10 year. It was not a detailed or prescriptive document but rather it was a framework guide and open to many different translations, (as is exposed in the later analysis of South African text-book coverage of this topic). The guidelines of this syllabus are not clear.

Another 'new' syllabus is being introduced at present and a summary of the core syllabus references to contour mapwork, to be examined for the first time in 1987 is displayed over the page.

STANDARD	REFERENCE TO CONTOUR MAPWORK
5	None
6	Introduction to the basic elements of a map.... contours.
7	1:50 000 topographic maps of South Africa (recognition of typical topographical features)
8	Reading, analysis and interpretation of 1: 50 000 topographic maps of South Africa - contours; cross-sections; gradients and vertical intervals; vertical exaggeration; and intervisibility. (Wherever possible the application of maps and aerial photographs should be integrated with relevant sections of the syllabus)
9	Reading, analysis and interpretation of 1:50 000 topographic maps of South Africa. (Topographic maps and aerial photographs should be used where appropriate)
10	Reading, analysis and interpretation of 1:50 000 topographic maps of South Africa. (Attention should be given to: . the drawing and interpretation of cross-sections. . the use and interpretation of topographic maps)
EXAMINATIONS PAPER 1 : (one and a half hours) . compulsory questions on photo and map reading, analysis and interpretation will be set. . the emphasis will be on interpretation and questions will relate to aspects of physical, settlement and regional geography.	

TABLE 2.1. CONTOUR MAPWORK IN THE NEW (1983) SOUTH AFRICAN CORE SYLLABUS

It is clear that something of a graded syllabus has been attempted for teachers to follow, with the main thrust being introduced at the Standard 8 level when the pupils (aged 15 to 16 years) are most likely to have reached the formal level of thinking, and this appears to be in line with the research findings investigated earlier. Skills to be introduced before Standard 8 appear to be the concrete thinking type. This new syllabus is much more satisfactory as a guideline than the earlier syllabus but it too may easily be misinterpreted by text-book authors who try to introduce difficult concepts too soon and without providing sufficient guidance. On the positive side the new syllabus, with its principles spelled out at the beginning and with teaching guidelines outlining a focus on graphicacy as introductory point 2.2.2., is a big improvement on earlier syllabus outlines for South African schools.

2.4 REVIEW OF TEXT-BOOK TREATMENT OF THREE-DIMENSIONAL MAPWORK, SOUTH AFRICA AND OVERSEAS.

Graves (1975) noticed a deficiency in British text-book treatment of geographical concepts saying that, it is surprising that few text-books used in geographical education are in any way 'carefully graded in the concepts which they present to pupils'. His view is reflected in a recent survey finding in South Africa,

> "The conclusion which may be drawn is that there are indeed doubts as to the suitability of text-books and that the teaching of geography particularly in the higher standards is hampered thereby" (H.S.R.C. Survey into the Teaching of Geography at South African Secondary Schools in the year 1966).

An analysis of text-books (Appendix B) used in South Africa shows that there is no consistent structured sequential framework for three-dimensional mapwork learning. Table 4 (page 50), displays a summary of books produced by four major publishing houses and it reveals certain inconsistent patterns. First there is inconsistency in the level at which they first introduce three-dimensional relief mapwork concepts. The first reference to relief mapwork is made at Standard 5 level by Juta and Nasou and both have simple 'island' map and profile views and an elementary text. The other two publishers only introduce contours at Standard 7.

The side-view or profile view, which requires an ability to abstractly twist the image through ninety degrees and therefore which requires higher order thinking, is also introduced at different levels by the text-book publishers. Juta, Nasou and de Jager-Haum refer to cross-sections at the Standard 7 level while Maskew Miller waits to Standard 8. All the accounts are 'dry' academic and unimaginative and consist mainly of detailed step-by-step instructions of the procedures involved in the construction of cross-sections.

Table 2.2. A summary of text-book treatment of contour mapwork in South Africa.

CLASS	JUTA	MASKEW MILLER	NASOU	DE JAGER - HAUM
STD 5	Window on the World (Holmes) Introduction with simple 'island' profile diagram.	–	Junior Geography for Std.5 (Knoetze et al) Introduction with a simple 'island' profile diagram.	–
STD 6	Window on the World (Earle) Contour definition and description Height estimation and steepness of slope.	–	Junior Geography for Std.6 (Barnard et al) contour definition characteristics landforms slope types	–
STD 7	Window on the World (Earle) cross-sections	Our Junior Geography Std 7 (van der Spuy et al) contour definition and an 'island' explanation. slope and contour spacing	Junior Secondary Geography for Standard 7 (Craig et al) cross-sections	Active Geography Standard 7 (Podesta et al) contour definition landforms cross-sections
STD 8	Geography 8 (Nel et al) Contour definition characteristics gradient landforms	Our New World 8 (Barnard and Nel) contour definition characteristics gradient cross-sections landforms map interpretation	Senior Geography for Std.8 (Swanevelder) contour definition characteristics landforms cross-sections	Active Geography Standard 8 (Podesta et al) contour definition characteristics landforms cross-sections gradient
STD 9	Geography 9 (Nel et al) Nothing	Our New World 9 (Barnard and Nel) Nothing	Senior Geography for Std.9 (Swanevelder) Nothing	Active Geography Standard 9 (Podesta et al) Nothing
STD 10	Geography 10 (Nel et al) map interpretation gradient	Our New World 10 (Barnard et al) cross-sections intervisibility map interpretation checklist	Senior Geography for Std.10 (Swanevelder) list of map exercises	–

It would appear that the only real consistency shown by all four publishing groups in their dealing with three-dimensional mapwork is the emphasis placed at the Standard 8 level on contour work. They each define contours and provide lists of contour characteristics, provide map and diagram 'models' of landforms and introduce the concepts of gradient and slope measurement. Again the text-book approach is 'dry' and lacking in imagination and this is particularly so with the introduction to contour concepts.

Figure 17, (opposite), is the page that introduces contours from the Juta text-book. It is reproduced fully so as to expose its shortcomings as a pupil reference. The page displays three pieces of information :

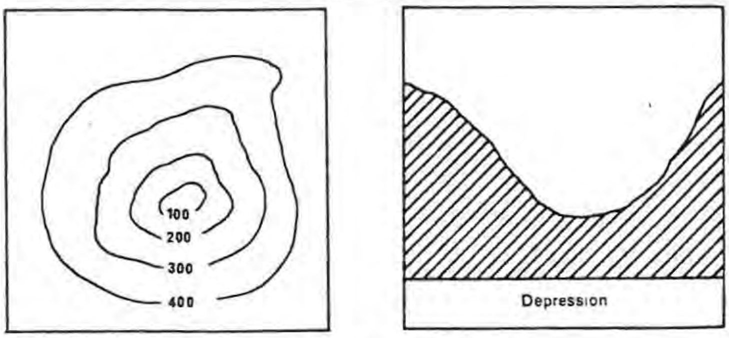
1. The text - an example of 'dry' unimaginative script.

2. Figure 1.7 - a photograph with white lines superimposed and without any guidelines or instruction. Although this reproduction is not a clear picture the original is as hidden. It is extremely difficult to visualize it as a photograph of a river valley with contours, and it is almost impossible to gauge a three-dimensional view.

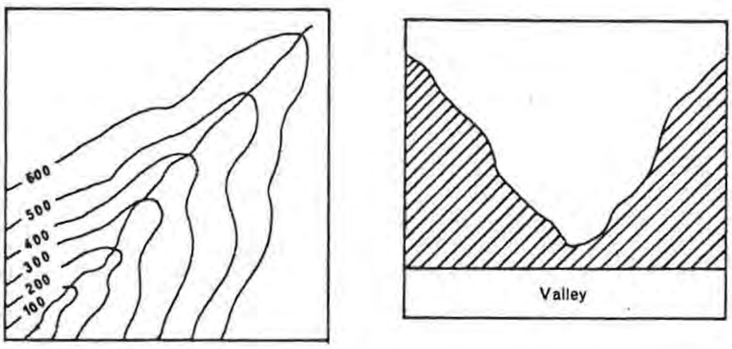
3. The profile of a bull standing upright. This diagram has no written explanation and it is presented without a key. The figure is spectacular but it is loaded with traps. An introductory page on contours, (which are horizontal lines representing vertical altitude levels in the landscape) should never be introduced as vertical lines representing horizontal levels or width. It is difficult to see how this method simplifies an already complicated concept, rather it appears to introduce an unnecessary deception, and a typical pupil response to the 'bull' diagram is, "I don't understand, Sir!"

The text-books are particularly weak in their presentation of material that requires the skill of perception of embedded shapes, (emphasised by Thurstone (1944), so as to recognise certain key landforms. Nasou presents this work at Standard 6 while the others leave it for later and most particularly for Standard 8 where its relevance is related to the geomorphology studied at this stage. A closer look at the Juta text-book draws attention to the weaknesses in this presentation and it exposes certain grave errors.

Selected diagrams from this book are analysed below with a critique under each :

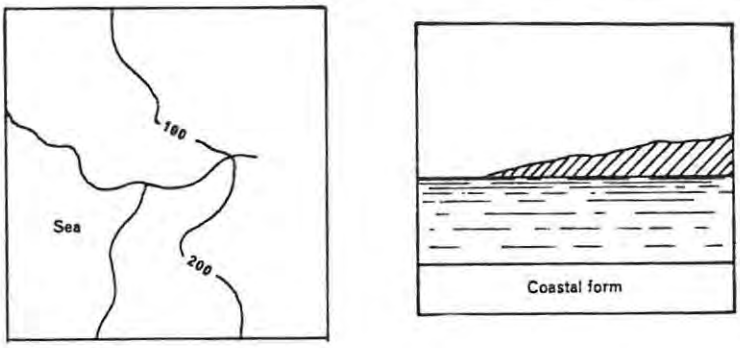


Depression - in Juta's Standard 6 text-book it states, "as a cartographic convention, contours are numbered so that the upper edge of the number is 'upslope'", and yet here in the Standard 8 book this convention is not observed. This is an oversight by the publishers that adds confusion to the pupil who is grappling with a difficult mapping concept.

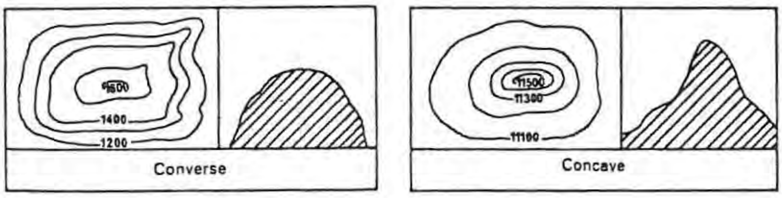


Valley - to an experienced eye it is clear that the cross section next to the map cuts across the valley but for the learner map-worker this is not clear and may lead to misunderstanding.

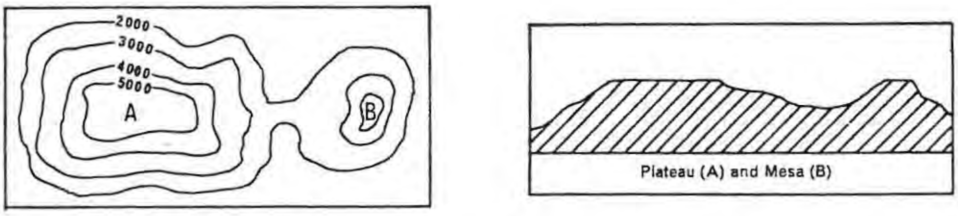
Figure 2.3.1. Selected contour diagrams from Geography 8



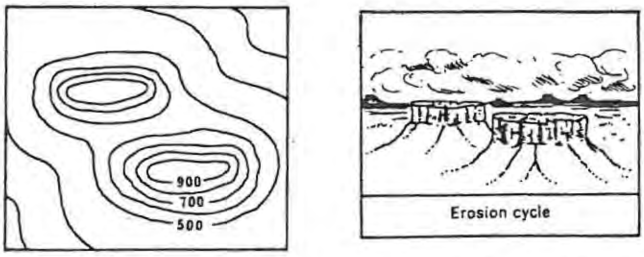
Coastal form - another very misleading diagram as it is not at all clear how the map relates to the contours.



Converse and concave slopes are not at all clear.

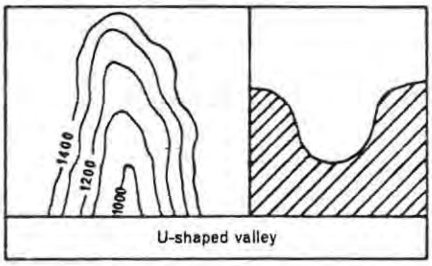


Plateau and mesa - again the labelling orientation is wrong which may lead to misunderstanding.

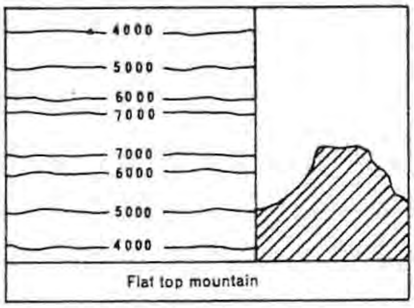


Erosion cycle, it is difficult to see how the author aimed to explain an erosion cycle with this diagram!

Figure 2.3.2. Selected contour diagrams from Geography 8.



U-shaped valley - at no point does a profile across this contour map yield a U-shape valley.



Flat top mountain - is another deceptive diagram because the contour shows a 'flattish' top 'ridge' and the flatness is not that clear as the summit contours are the same distance apart as the 5 000 to 6 000 and the 4 000 to 5 000 contours. Neglecting label orientation once more complicates the concept.

Figure 2.3.3. Selected contour diagrams from Geography 8

It is distressing to note that none of the text-books examined had any mapwork in the Standard 9 books. This means that a pupil effectively has to remember concepts over twelve months if he is using his text-book and hope that the Standard 10 text 'revisits' earlier work and reinforces it. Unfortunately this is not the pattern. At the final matriculation year of Standard 10 the text books again are inconsistent in their presentation of material. Juta's Geography 10 reports fully on how to determine gradient and how to interpret three-dimensional aspects of mapwork. Maskew Miller's Our New World 10 has a full description of how to draw profiles up irregular vertical paths, intervisibility and profuse notes on how to interpret relief maps followed up with a check list. Nasou's Senior Geography for Standard 10 merely gives a list of map exercises without reference text. Each text has its merits and a combination of all three would perhaps make the best handbook for the matric student preparing for examinations. Individually the books fall short of his needs.

This examination of text-book coverage of three-dimensional mapwork from Standard 5 to Standard 10 has exposed an inconsistency by text-books to introduce concepts at the same level and it has also uncovered material that is misleading and erroneous. For those teachers and pupils in South Africa who rely on text-book prompting, this situation is serious. It is particularly serious for a pupil who moves from a school that uses one text-book to another school that uses a different one. It is also serious for a pupil who misses a year of geography as there appears to be no careful grading (as warned by Graves p. 49), and there is no 'revisiting' of concepts as Bruner would recommend.

Because mapwork is stressed in the syllabus and examination (where there is a compulsory and separate examination paper for mapwork and where mapping accounts for a fifth of a matriculant's final geography mark), Nasou and Shuter and Shooter have published mapwork text-books. Both of these texts are pitched at senior secondary pupils and both fail to present material in a sequential graded manner.

Working with Maps (Nicolson and Morton, 1966) starts on page 2 with gradient, before contours are even introduced. The material is given in an unappetising mathematical form. Page 5, then, describes relief mapping methods with a definition of contour lines. Contour mapping follows and is the chapter heading on page 7 and the text starts with a complicated interpolation exercise before it explains how to understand contours. A selection of eleven landforms are then displayed after a warning that,

> "...there is no point in trying to learn them. Mapwork is not so much memory work as a matter of understanding contours...this cannot be done by rote learning."

Cross-sections and map description is the chapter heading for the next chapter where the procedure is explained, vertical exaggeration outlined and map description analysed somewhat sketchily. The strength of this book is the number of practical exercises (with a teacher's answer book) and this is a decided advantage over the other general text-book presentations. Chapter 4 Map Interpretation completes the instruction on relief concepts.

The most recent text-book publication in the field Map and Aerial Photograph Reading and Interpretation for Secondary Schools (Shah, Shah and Naidoo, 1982) is not much of an improvement on the earlier books.

Relief mapwork takes up twenty one pages near the beginning of the book, but almost all of these are more than half filled with the map examples of landforms. Methods of representing relief are given prominence but explanation is missing. After a short paragraph on contour interval a step-by-step account of how to construct a profile is presented with notes on choice of vertical scale, intervisibility, gradient and types of slope. These slopes are more clearly presented than in the earlier texts because the map has a line across marking the line of the profile view. An analysis of twenty landforms fills the rest of the chapter with large maps and short inadequate text accounts.

It is clear that text-book writers in South Africa have the final matriculation examination uppermost in their minds when they write their texts. All the books reviewed above take little care to pitch the material at the stage of secondary schooling that at which the pupil might be, and this is particularly the case at the lower secondary school level. The style of presentation is factual and without imagination. In a different style, Mapwork (Proctor, 1983) published by Edward Arnold for 11-14 year old pupils in Britain makes a pertinent contrast. This text-book, which is part of the 'Foundation Geography Series', is not examination orientated but rather states its aim to be 'modern and imaginative' and yet to 'provide the solid foundation in skills and concepts which geographers have traditionally sought in the first years of secondary schooling'.

The style of this text certainly promotes interest. Facts are not so much given as gleaned from question and answer technique. The first map is a Pirate's map of Hook Island with 'treasure', 'wreck' and 'snake mountain' firing the imagination of the young user, on a 'parchment-style' map written in a Gothic script, and there is a modern contour map on the same scale set below. Contours are then introduced and instead of vertical profiles being used to demonstrate slope types, (as all the South African texts do) oblique views using three-dimensional blocks give a much more creditable first view of the relationship between the horizontal and vertical planes. Landforms, too, are presented imaginatively in contrast to the mundane illustrated lists in South African texts. Proctor suggests a simple cardboard model-making method for analysing landforms. This is clearly a much more positive reinforcement method of learning concepts than the negative warning against rote learning in Working with Maps quoted earlier. Cross-sections are introduced in a question and answer method rather than the wearisome and restrictive step by step lists that the South African authors have preferred to employ. The questions promote thought, for example a profile is shown across an island and a question asks how will a line at right angles across this line differ in profile view. The section on relief mapwork is completed with a practical section looking at Ordnance Survey mapped relief.

Another British publication that offers a contrast with its South African counterparts is the Mapwork One and Mapwork Two books (Kemp, 1983) recently produced. Again these two books are not as examination-facts orientated as the local books, although Mapwork Two has as its aim 'a clear and straightforward explanation of essential map interpretation skills and techniques which pupils will need to answer mapwork questions at CSE and O Level'.

Mapwork One introduces skills and basic ideas and then Mapwork Two revises these and develops new concepts and skills relevant to examination courses. This is an approach that would appear to be more in line with the thinking of Bruner and one more likely to be successful than the 'fact' based South African books. Mapwork One introduces contours in a question and answer style but unfortunately profile side views are used to correlate with the map from above. The main difference between this and the local texts is found in the exercises attached to the script. Kemp sets a photograph of a mountain rescue team which is midway up a steep slope above a map which is orientated to present the same view. A variety of tasks relating to a rescue are set and they involve skills of cross-section drawing, contour intervals, interpolation height estimation, slope distance, and slope steepness, and all the exercises are given relevance and therefore promote motivation. Another task is set around a photographic view of Montborough Dam and a map of the same valley, pre-flooding. The questions relate to the rise in water level and the potential results of its inundation of the landscape.

Mapwork Two reinforces the skills developed in Mapwork One and then introduces gradient calculation with reference to road signs that indicate slope steepness. More complex cross-section exercises, and matching contour patterns with oblique three-dimensional block views of valleys follow.

Other recent texts emanating from British authors point in the same direction. Batenham and Martin (no date given) in the Series Steps in Geography provide a series of three-dimensional oblique block diagrams to introduce contouring concepts and some simple incomplete profiles. Cole and Beynon (1980) in New Ways in Geography pitched at Standard 5 or 6 level set a dam flooding a valley situation to explain contouring concepts. Evans (1978) in the series The Young Geographer pitched at the middle secondary school level offers a variety of question and answer situations and techniques of making models.

The new approach promoted by the British texts invites a response in South Africa. Perhaps the Standard 6 to Standard 8 texts should be reconsidered in relation to the imagination and motivation of children between the ages of 13 to 15 and not, as they are at present, in relation to an examination for 17 and 18 year olds. Ballantyne (1985) has set the example with his three mapwork books at the Primary School level and there is now a need for a concept-based mapwork textbook for South African secondary schools that encompasses all the skills required of the secondary school syllabuses.

2.5. REVIEW OF PAST EXAMINATION QUESTIONS.

The examination is the final goal of secondary schooling and the influence of examination questions on the teaching of three-dimensional mapwork must therefore be strong. An attempt to gauge this influence is now made by examining a sample selection of recent past questions. The sample has been chosen from papers set by nine Examining Boards and they are:

1. Department of Education Cape of Good Hope Senior Certificate Examination. (Cape)

2. Department of Internal Affairs Division of Indian Education Senior Certificate Examination. (Indian)

3. Department of Internal Affairs Senior Certificate Examination. (Internal)

4. Joint Matriculation Board Matriculation Examination. (JMB)

5. Natal Education Department Senior Certificate Examination. (Natal)

6. RSA Department of Education and Culture National Senior Certificate Examination. (National)

7. Orange Free State Department of Education Senior Certificate Examination. (OFS)

8. The Republic of Transkei Department of Education Senior Certificate Examination. (Transkei)

9. Transvaal Education Department Senior Certificate Examination. (TED)

Past papers, over the last eight years, from these examinations, with a focus on Cape and JMB and recent samples from the other Examining Boards have been analysed. In a search for pattern and structure, the first analysis is a test of the significance attached to three-dimensional mapping concepts by the different boards and it is gauged as a percentage of the total map reading mark and is shown graphically (Figure 2.6.) It is immediately noticeable that there is no apparent pattern. The range of emphasis is from a lowest 0% to a highest 53% of the total mapwork mark in any one examination. Nor is it clear that there are any differences between Higher Grade and Standard Grade with the range for Higher Grade from 0% to 53% and for Standard Grade from 0% to 47%. The eighty examination papers investigated indicate an average 18% of the total marks for the mapwork section being allocated to three-dimensional aspects. The average for the Standard Grade was 17% and for the Higher Grade it was 19%. The problem that these figures highlight is the unpredictability of the significance attached to three-dimensional graphicacy by the Examining Boards which is shown by the random nature that marks have been allocated in this investigation sample. Clearly in examining the whole range of mapwork skills, they have not been able to be consistent in three-dimensional mapwork coverage.

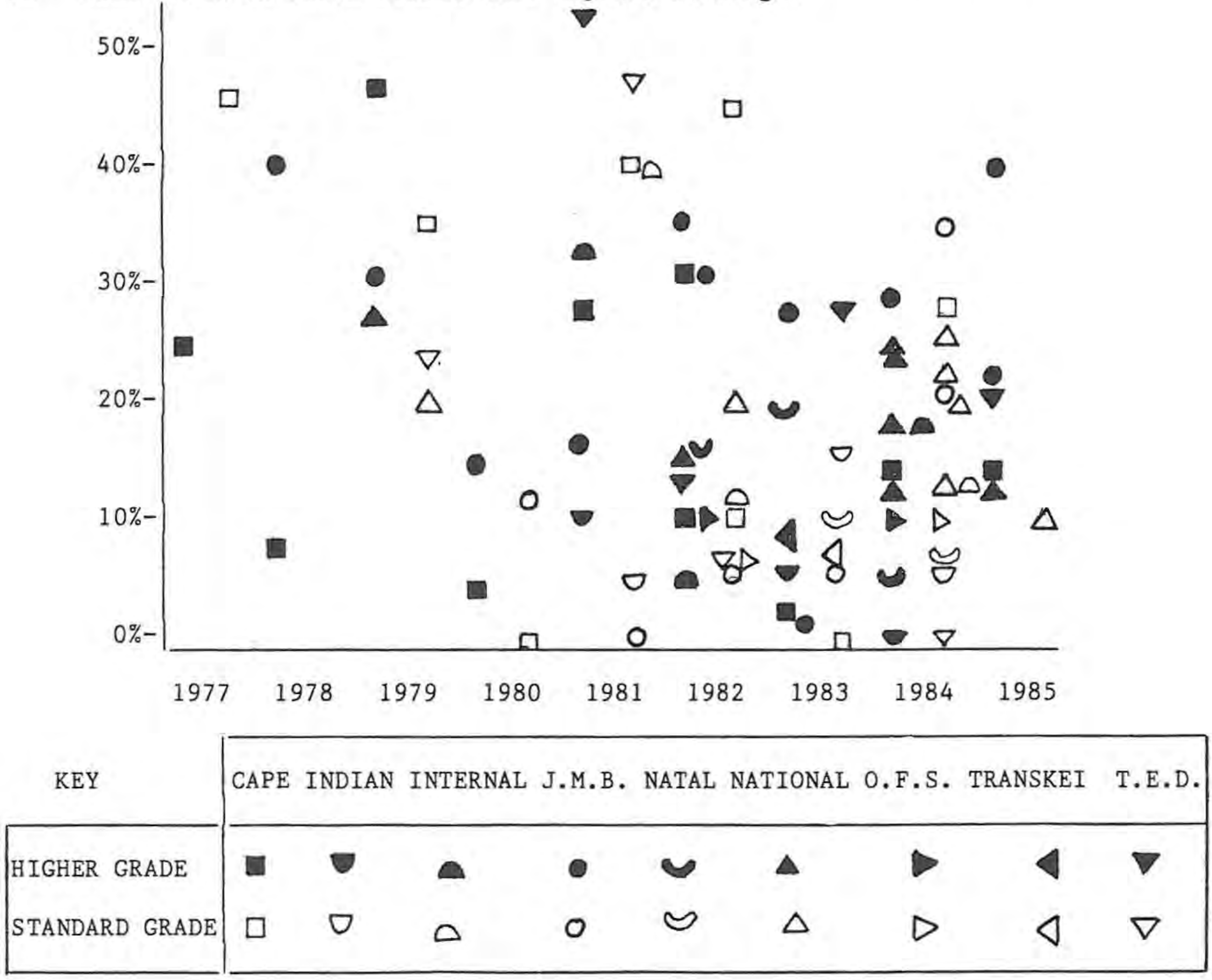


Figure 2.4. Emphasis on three-dimensional aspects of mapwork in South African secondary school final examinations shown as a percentage of the total mapwork marks.

A scrutiny of the questions employed in these examinations shows another random pattern and it suggests a haphazard and structureless questioning approach to this part of mapwork by the different examiners. A classification has been devised below, following Bloom's Taxonomy of Educational Objectives for the Cognitive Domain (1956) so as to evaluate the structure of the examination questions of three-dimensional mapwork. This plan could be considered as a preliminary classification that could perhaps lead to later research and a proper ranking. The example questions in Table 2.3 are numbered so as to be referred to by the later analysis of examination questions.

I KNOWLEDGE AND DEFINITIONS	An emphasis on factual recall, rote learning aspects and including mathematical calculation. eg. 1. Definition of contour interval 2. Definition of vertical exaggeration 3. Definition of gradient 4. Definition of elevation
II PERCEPTUAL INTERPRETATION	Detection, discrimination, identification, recognition, interpretation and synthesis. eg. 5. Identify relief feature from the contours 6. Slope description from contour patterns 7. River flow direction from contour patterns 8. Describe a landscape view from contours
III MAPWORK DRAWING SKILLS	Perception and then application by drawing skills eg. 9. Draw (or complete) a profile 10. Identify features on a profile 11. Intervisibility 12. Measure overland distance 13. Contour sketches from verbal description
IV INTERPRETATION AND ANALYSIS	Inter-relationships and analysis eg.14. Influence of relief on communications. 15. Influence of relief on man-made features. 16. A regional description and subdivision.

Table 2.3. A classification of examination questions used in final school examinations in South Africa.

The analysis yields the following pertinent points:

a. Marks allocated to different skills range widely. For questions on landscape views, a very popular question asked by all the examining boards, the JMB, Cape and National Boards allocated high marks in the region of 15% to 20% while the OFS Board gave only 2,5%. Even within one Examining Board there is a range, for example the JMB allocated this question 2,5% in two separate examination papers.

b. The most frequently set questions were:
   i. Identify landforms from contour patterns (the mark range for the sample was from 1,2% to 18,3%)
   ii. Gradient calculation (and here too marks ranged from 2,5% to 15%).
   iii. Estimation of elevation (this simple skill was allocated 15% in a National paper while it averaged only 2,5% with the other exams.

c. Mark emphasis ranked gradient calculation as the most popular followed by identification of features from a profile and then identification of features from contour patterns on the map.

d. An estimate of significance by assessing the average marks given for each question indicates that landscape view descriptions are the most important. The next most significant questions by this method are identifying features on a cross-section or profile, drawing or completing a profile and gradient calculation.

e. There is no apparent difference between the questioning patterns at the Higher Grade and questioning at the Standard Grade. One would anticipate a different format or a different emphasis in mark allocation, but this is not apparent.

f. By ranking the skills involved in three-dimensional graphicacy it was hoped that some pattern might be discerned, but there does not appear to be even a tenuous one. The method of analysis involves totalling the marks allocated to each rank and dividing this by the number of questions in that section. The results are shown below:

RANK	TOTAL MARKS	NUMBER OF QUESTIONS	AVERAGE MARKS
1	182	54	3,37
2	485	62	7,82
3	267	42	6,36
4	190	36	5,28

Table 2.4. Analysis of examination questions by rank.

It could be argued that the average should rise with rank so that the simple recall skills should be given a lower average than the higher interpretive skills, but once more no such pattern is apparent. The interpretive skills are given low emphasis and there is no difference between Higher Grade and Standard Grade examining.

2.6. QUESTIONNAIRE TO TEACHERS.

A questionnaire was compiled to test the responses of geography teachers to five topics :

a. When should contour mapwork be introduced?
b. How should contour mapwork be introduced?
c. Text books.
d. Examinations in mapwork.
e. General thoughts on the topic.

Because of the time constraints it was decided to test a small convenience sample of teachers in Grahamstown. The sample is considered to be reasonably representative of a wider range of teachers at the secondary school level as it comprises a variety of situations.

Teachers	School Name	School Type
3	Graeme College	Government school for white English-speaking boys.
1	Victoria Girls High School	Government school for white English-speaking girls.
4	Kingswood College	Private co-educational school for English-speaking mainly white pupils.
3	St. Andrew's College	Private college for English-speaking pupils of all races, but mainly whites.
1	Hoerskool P.J. Olivier	Government co-educational school for Afrikaans speaking white pupils.
1	Diocesan School for Girls	Private school for English-speaking pupils of all races, but mainly whites.
1	Nombulelo Senior Secondary School	Government school for Blacks

Table 2.5. Teacher sample for the opinion questionnaire.

The fourteen teachers who responded represent nearly all the secondary school geography teachers in Grahamstown (only one teacher from Marywaters Secondary School for Coloureds did not return a questionnaire in time). An important feature of this survey sample is the number of years of teaching geography that they have accrued. It represents 206 years for an average of 14,5 years per teacher and a range of experience from thirty-three years to, a straight from University preparation, one year.

No pilot study was initiated because of the smallness of the local testing population. In order to encourage a one hundred percent successful return (that nearly resulted) the questionnaire was handed to each teacher in person and a letter that explained its motives accompanied it. The letter and the questionnaire may be examined in Appendix D.

It was hoped that the opinions of the Grahamstown teachers might add to the views of the researcher and help to highlight and to put the teacher's view in perspective. For these reasons the results of the questionnaire are reported fully below. The teachers were asked for a short direct answer to a specific question and then they were allowed to elaborate their views in a paragraph. It is significant that all the teachers elaborated on their responses despite the fact that the questionnaire was delivered at the busy end of the year period. This may be taken to indicate the importance that each teacher attached to the topic.

Three questions probed teachers' views on when contour mapwork should be introduced. The first asked for opinions about the value of a junior school preparation, and eight teachers were doubtful. But this response displayed a weakness in the question set as it did not specify contour mapwork. This became apparent when the teachers elaborated on their views as the six teachers who had not expressed doubt qualified their responses to mean that some introduction to mapwork was valuable but that contour skills should be left for secondary school. One teacher, however, reported enthusiastically of success in hiking and contour mapwork with Standard 5 pupils.

The second question asked for a vote either in favour of Piaget's view of a passive early approach or in favour of Bruner's early introduction of concepts and 'frequent revisiting'. Nine teachers were in favour of Piaget's view confirming the majority view expressed in Question 1. Two expressed the view that this is particularly pertinent with girls who 'have difficulty with the third dimension anyway', and the teacher at the Black school stressed Piaget's view with respect to Blacks. The third question asked when contour mapwork was introduced at their school. Twelve answered 'in Standard 6', only one before and one after, although three teachers felt that delaying introducing contour mapwork to Standard 7 had distinct advantages.

The second topic tested was 'how contour mapwork should be introduced' and four questions were set. The first question asked if a start should be made with the local map sheet. Only two answered, 'yes' and the general opinion was that 'it would be a mistake to start on 1:50 000 sheets before basic concepts had been clearly taught.' One teacher noted that 1:50 000 maps are 'too cluttered with irrelevant information'.

Thirteen teachers indicated that they used models, and the one who did not, indicated that he would like to use a model. Several teachers saw that the main value in using models came when the pupils participated in their construction. When asked if they used other aids ten wrote 'yes'. The other aids that they listed were, overhead projector, epidiascope, films, videos, slides, photographs, stereo photographs and stereoscopes, and even a dress maker's hemming rule.

When asked to describe an ideal programme for teaching about contours six teachers stressed the importance of using models. All emphasised the importance of a simple introduction and a progressive programme towards the more difficult concepts. One suggested a move from easily identifiable man-made features to the natural landscape. Another considered it important to regularly revisit mapwork with exercises, and one method reported to be most successful required pupils to draw in rivers on a simple contour map.

The third topic investigated was that of text-books. Very few teachers indicated that they used text books although seven used the specialised specialised Working with Maps (Nicholson and Morton, 1977) after Standard 8. Almost all teachers were left to their own devices for earlier contour mapwork and eight reported that they had built up their own courses. When asked for their assessment of available texts all the teachers felt that texts were lacking in most respects. Some of the criticisms included 'insufficient number of graded examples', 'very poor indeed', and 'they are unimaginative, usually progress too rapidly, and do not have much pupil appeal'.

Teachers were then asked if they thought the order of presentation of contour concepts in text books is graded, sequential and suitable for the pupils to whom it is pitched and the reply was a unanimous 'no', without any further qualification. Anticipating this reply the next question asked if teachers thought that there was a need for a suitable text-book and the answer was unanimously 'yes'. It is clear that the teachers of this sample group were dissatisfied with the text books available.

The next topic questioned was the topic of examination evaluation. Noting that mapwork is a compulsory question in Matric the teachers were asked if they thought contour mapwork is properly tested in the final examination. Two were non-committal, two indicated that it changed from year to year, two were happy and eight teachers gave negative responses. It must be noted that the schools represented by these teachers offer matriculation candidates to three Examination Boards, namely the Joint Matriculation Board, the Cape Senior Certificate and the National Senior Certificate Boards. When asked if their pupils performed satisfactorily in contour mapwork nine claimed that their pupils underperformed. It was noted that 'girls have a great deal of difficulty in seeing 3-D', that the Blacks 'struggle with topographical map work'and that 'weaker pupils tend to do badly'. When the teachers were asked if the examinations appeared to be well structured or to be haphazard nine teachers gave negative replies. Several teachers felt that the situation altered year by year and therefore the situation was unpredictable. In general it would appear that most teachers felt that the examinations fell short of effecting a proper structured evaluation.

Finally teachers were given an opportunity to record any viewpoint that they considered pertinent under a heading 'your thinking'. Some interesting points made include :

'we tend to move off easier/basic things too quickly, the boys need to be drilled into the basics more thoroughly',

'there is a need for a comprehensive guide to teaching mapwork (A Teachers' Handbook)',

'there is no doubt in my mind that children should have to actually walk up and down slopes', and

'mapwork gets squeezed out by the bulk of the total syllabus'.

It is clear that the teachers in this sample expressed a view that problems in three-dimensional mapwork teaching are found in the shortcomings of text-books and in the final examination questions. This would appear to substantiate the earlier findings in this chapter.

CHAPTER 3

TESTING SOME MAJOR RESEARCH STUDIES

3.1. INTRODUCTION TO THE EXPERIMENTAL INVESTIGATION

This chapter reports on attempts to simulate, in a South African secondary school situation, certain key studies that have been described earlier in Chapter 1, and to test their significance. The method of duplicating published research investigations has been chosen because it allows certain comparisons to be drawn between established findings and the results obtained in the local tests.

It should be stated unequivocally that the research reported here is of an exploratory nature, aimed at the identification of problems rather than the solution of problems. The experiments are only intended to act as pilot studies or indicators for further research as their significance is very limited. The results of the studies, however, offer very interesting parallels with the model experiments from which they have been copied but despite this no wide application is sought from the findings.

The broad aims of the experiments are threefold:

a. To test how far children of different ages have an understanding of, and have developed skills in, contour mapwork so as to suggest an optimum stage at which to introduce contour mapwork at schools.

b. To test some perceptual and conceptual processes and difficulties involved in contour mapwork so as to ascertain the best teaching programme.

c. To test the correlation between three-dimensional thinking skill performances and contour mapwork test responses so as to reinforce the conclusions of the first experiments.

Administration of the experiments.

The method of developmental research that was chosen was cross-sectional rather than longitudinal because of the time constraints and cost factors. For the same reason the pilot studies all involve an accidental or convenience sampling method. The range of respondents is from classes of pupils from 10 year-olds in Standard 4, to 17 year-olds in Standard 9. The samples have all been taken from Kingswood College in Grahamstown because, as a co-educational school, it has a wide range of boys and girls from primary classes to matriculants in Standard 10. A significant factor is the dichotomy between Junior School pupils who have had no formal tuition in contour mapwork and College pupils who are introduced to contours in

Standard 6. Most children are 13 years old at this transition stage.

Inevitably subjects varied in their experience even at the same educational level, but no attempt has been made to measure the impact of such variation nor to differentiate it from the effects of variations in intelligence, achievement or motivation. Similarly, the influence of particular teachers, of the home environment and of the attitudes of peer groups was ignored. By working within this school the accessibility to pupils has made it possible to test conveniently within the 'free-time' time-table of the school day and without disrupting the teaching programmes at this or at any other school. The pupils were allowed to undertake the tests anonymously and they were only placed on a forty minute time constraint for each test, as this represented the duration of a class period, although none of the pupils found any difficulty in finishing any test within thirty minutes.

The accounts of these experiments follow a uniform format -

(a) a description of the model research study,
(b) a description of the Kingswood experiment,
(c) the results of the Kingswood experiment,
(d) comment on the experiment.

Copies of the tests that were administered can be found in Appendix E.

3.1.1. Experiment 1 (Contours and Profiles).

(a) The model research study.

The investigation into children's ability to interpret contour lines by the Training College Group Committee of the Geographical Association (1941) is the model for the first pilot study. The exemplar investigation aimed to discover how far children learning geography have a complete understanding or accurate imagination in the field of contour mapping and the results were published.

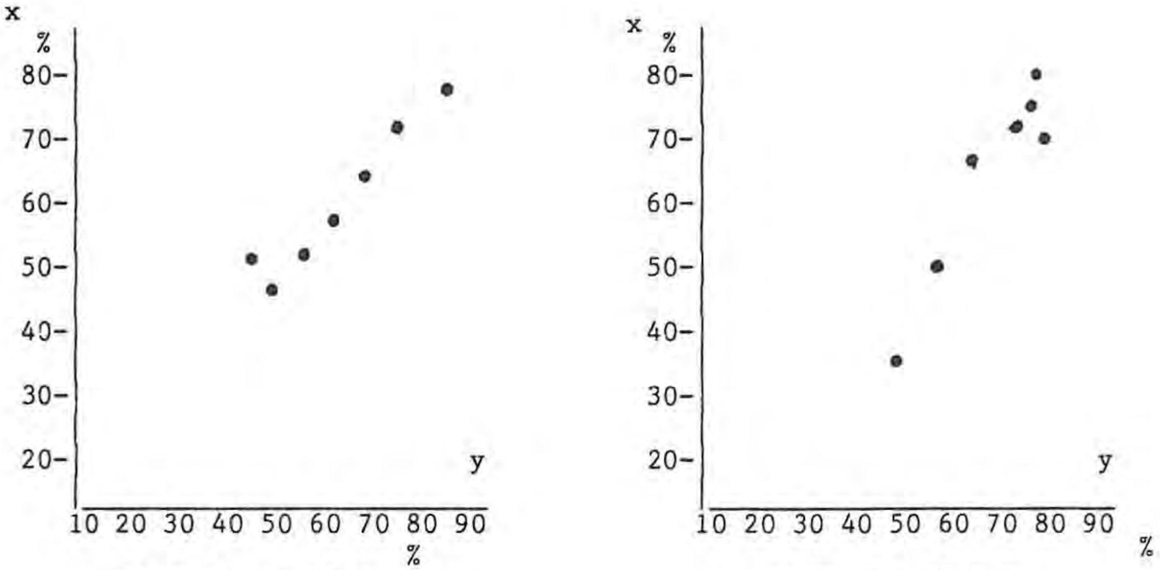
(b) The Kingswood experimental study.

A duplicate study was attempted which aimed to determine if there was a significant correlation with the model investigation and then to compare the findings. The assumption was that there is a significant correlation between the 1941 investigation's findings and the situation studied at Kingswood.

The research design replicates the model study because nearly 40 000 pupils were tested in the model experiment and the results must therefore be considered to have been valid and acceptable as a prototype. In the Kingswood study a sample of 221 pupils was tested with identical exercises that had the illustrations photocopied from the 1941 report and then these were enlarged so as to improve the viewing. The tests may be referred to in Appendix E.1. and for a full description of these tests the reader may be referred back to page 35. The null hypothesis investigated is that there is no significant relationship between the responses to the tests by the 1941 sample of children and the responses to the same tests in the 1985 Kingswood experiment.

(c) Results of the Kingswood experiment.

The results of the first tests appear to display a clear positive relationship when they are represented graphically with scatter diagrams. (page 69)



GRAPH A - TEST 1   GRAPH B - TEST 2

x axis - Kingswood test results per age group
y axis - 1941 test results per same age groups

Figure 3.1. Correlation scatter diagrams of samples of answers to children's interpretation of contour tests.

To test the significance of these correlations the product-moment correlation coefficient parametric method has been used. It would appear that the conditions are satisfied whereby the observations are independent, from normally distributed populations, the populations have the same variance, the measurements are on an interval scale and the graphs above reveal a linear distribution. The data for the product-moment correlation is shown in Appendix F.1.

The correlation coefficient (r) values for the two tests were found to be $r = 0{,}98$ and $r = 0{,}91$. Using the Student's t test of the significance of r the null hypothesis was rejected at less than the 1% level of confidence for both r values.

The line drawings below indicate that for both studies there is a steady rise in ability to relate solid form to contour symbolism from 12 to 16 years of age.

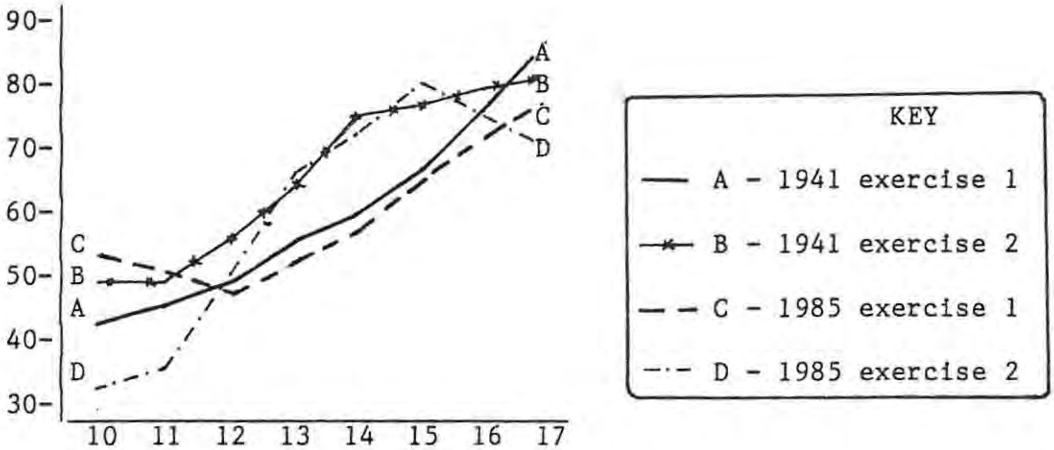


Figure 3.2. Graph comparing the percentages of correct answers for the two exercises from pupils of given ages.

Both sets of results indicate that Exercise 1, relating a picture to one of four maps, made more demands on the imagination than did Exercise 2. The falling off in the rate of rise for Exercise 2, where pupils were confronted with one map and four panoramic sketch views, from about 15 years of age reported by the Training College Group Committee, (indicated by line B on Figure 3.2) is reflected by the drop from the age of 15 at Kingswood, (shown by line D).

At Kingswood mapping is not introduced until the pupil is in the senior school so that 11 year-olds and some 12 year-olds have not been taught mapwork. It is worthy of note that for Exercise 1 the model study indicated a break at the age of 10 years and while the Kingswood experiment also indicated a similar break after the age of ten (ten year olds achieved 60% for Exercise 1 and 55% for Exercise 2) the sample size of only fifteen pupils is too small to have any statistical significance, and has not been reported.

(d) Comment on the experiment

In general the results of this experiment suggest that pupils can interpret shape correctly from contour lines more often and at a younger age than is commonly supposed. This intuitive ability of children who have not been taught three-dimensional mapwork is a pointer for further research, especially in connection with the abilities of younger children.

3.1.2. Experiment 2 (Contour Proficiency Tests).

(a) The model research study.

Contour skills were further investigated by using Boardman and Towner's (1979) experiments as a model. The model study investigated some of the problems encountered by older pupils when reading and interpreting topographical maps. The tests which cover a range of map reading skills and which were administered to 578 15-16 year olds in Britain, can be referred to in Appendix E.2. and for a full description of the tests the reader is referred back to page 37.

(b) The Kingswood experiment.

The test was set to 267 pupils at Kingswood College aged from 10 to 17 years. The aim was, therefore, different in that the responses of a range of age groups was tested so as to analyse any emerging patterns. The tests were concerned with ascertaining the pupil's ability to visualize the third dimension by questions that tested an understanding of relief by height estimations and slope interpretations from the map.

(c) Results of the Kingswood experiment.

In the model study the apparently straightforward task of relief shading showed a big range in abilities from 80% correct answers for the O-Level candidates to 17% for the GYSL candidates and the authors estimated that half of the pupils tested had an incomplete understanding of what a contour map represents. The Kingswood study showed a significant drop from the age of 13 where pupils younger than this, and without tuition in contour mapping clearly failed to understand contours.

The second task was to assess which end of a short line was the higher. Again the results up to the age of 13 are very different from those of older children. The untaught group could not visualize slope direction on the contour map. The one major anomaly, however, was the surprisingly high percentage of correct responses for line D which should perhaps have been the most difficult to visualize because the line lay parallel to and not at right angles to the contours. Most young candidates put their small circle response in the middle of the B line. The answers had probably been prompted by the alignment of the short lines with the page margins. 'Highest' was translated as the top of the page so the answers to lines A and C were wrong because the highest end pointed down to the bottom of the page. The pupils made the otherwise inexplicable response of circling the centre of the line B because it lay parallel with the bottom of the sheet and line D was the only line with the correct end pointing towards the top of the page.

The remaining questions tested the pupil's ability to read contour heights at marked points. Point E was the easiest, because it lay on a contour, and predictably it attracted the highest percentage of correct responses. Points F and G were more difficult to estimate because they lay between contour lines. The dichotomy between younger untaught and older children who had received tuition is very distinct with children under the age of 13 recording very few correct responses. The fact that scores from pupils over 13 years old upwards increase steadily with age suggests that understanding of relief as shown on contour maps develops steadily with age as pupils enter the formal stage of thinking.

The results of the Kingswood test performances are summarised below :

TEST TYPE	AGE IN YEARS 17	16	15	14	13	12	11	10	* BT
Relief 3	83	58	51	56 |	30	6	6	8	49
Relief 2	11	35	37	29 ↓	22	6	14	16	24
Relief 1	3	6	6	6	12 ↓	16	23	16	15
Relief 0	3	1	6	9 ↓	36	72	57	60	12
Line A	89	87	77	78 ↓	58	38	11	9	75
Line B	94	85	84 |	78	58	38	20	10	85
Line C	94	85	83 ↓	78	58	28	20	9	81
Line D	89 ↓	73	71	63	45	50	83	83	77
Steepest	94	78	74	73	55 ↓	16	20	25	54
Point E	100	88	77	75 |	45	6	17	2	65
Point F	94	81	77	75 |	33	3	6	0	40
Point G	94	79	77	72 ↓	36	3	6	2	59
SAMPLE NUMBER	36	52	35	32	33	32	35	12	

* Boardman and Towner's total results.
↓ Locating Boardman and Towner's totals in relation to the Kingswood results.
(All performance marks are percentages)

Table 3.1. Scores on Boardman and Towner's (1979) tests of relief understanding as recorded by Kingswood pupils.

(d) Comment on the experiment.

Boardman and Towner's tests were very effective in testing a range of abilities and the means of their overall testing averaged about the same as for thirteen and fourteen year old Kingswood pupils in most of the test items. The sudden drop off in performance by Kingswood pupils under this age is very noticeable and more than underlines an inability to guess the meaning of contours as the young pupils have not yet been introduced to the meaning of contour symbols.

3.1.3. Experiment 3 (Contours and Profiles).

(a) The model research study.

A key study that investigated conceptual and perceptual difficulties in contour interpretation by Griffin and Lock, (1979) has been used as a model with which to investigate local responses. The test used can be referred to in Appendix E.3. and for a description of their tests the reader is referred back to page 38. Griffin and Lock posed a wide range of questions :

a. Is the contour concept a difficult one to comprehend fully?

b. At what educational level is the introduction of training procedures appropriate?

c. What are the most common forms of misinterpretation of contour assemblages?

d. Is there any pattern to the occurrence of such errors?

e. Are such image-creation and recognition activities in harmony or in conflict with the standard functioning of visual perceptive abilities?

They tested a total of 701 subjects in six educational groups ranging from senior secondary to tertiary levels.

(b) The Kingswood experiment.

At Kingswood similar tests were applied to 189 pupils aged from 13 to 18, all of whom had received tuition in contour mapping. Twelve questions set in graphic form displayed a contour pattern with a profile line marked on it and five line profiles marked A to E were offered as optional answers. Pupils received a separate answer sheet on which the instructions were set out and these were also explained verbally so as to avoid any misinterpretation. Three of the questions exhibited circular contour patterns and the remaining nine employed realistic contour patterns with labels properly orientated but without any indication of drainage. Questioning was devoted entirely to uniform, concave and convex slopes (all of which are introduced in South Africa by Standard 6 text books).

(c) Results of the Kingswood experiment.

Griffin and Lock had identified five types of error on the convex/concave maps and a further two on the uniform slope maps, and these were used to tabulate their results. These errors are defined below, (and refer to Figure 3.4. shown opposite)

Presuming profile (a) opposite to be correct :

E1 Height-reversal.
This indicates a realisation that steepness of contours are correctly placed but a failure to realise the relative heights of the two ends of the profile. (shown as (b) opposite)

E2 Slope-reversal.
The correct judgement of relative heights of the profile is given but the notion of changing steepness between them is inverted. (Shown as (c) opposite)

E3 Height-and-slope reversal.
The combination of errors designated E1 and E2. (Shown as (d) opposite)

E4 Variable-slope-denial.
These answers show correct interpretation of relative elevations but substitutes a uniform for a continuously changing slope. (Shown as (e) opposite)

E5 Variable-slope-denial with height-reversal.
This combines the faults of E1 and E4. (Shown as (f) opposite)

E6 Variable-slope-assertion.
Where the answer should be a uniform slope and a continuously changing slope is recorded. (Where (a) is an example of the convex case and (c) of the concave case).

Using the same classification the Kingswood results are listed over the page as Table 3.2.

CONCAVE/CONVEX SLOPE QUESTIONS

AGE	SAMPLE SIZE	POSSIBLE ANSWERS	CORRECT ANSWERS	ERRORS E1	E2	E3	E4	E5
18	4	40	26 (64%)	1 (3%)	6 (15%)	2 (5%)	4 (10%)	1 (3%)
17	20	200	139 (70%)	9 (5%)	25 (12%)	8 (4%)	15 (7%)	4 (2%)
16	53	530	307 (58%)	48 (9%)	59 (11%)	41 (8%)	62 (12%)	13 (2%)
15	55	550	306 (56%)	49 (9%)	87 (16%)	40 (7%)	49 (9%)	19 (3%)
14	42	420	237 (56%)	23 (5%)	48 (12%)	37 (9%)	48 (12%)	27 (6%)
13	15	150	74 (50%)	8 (5%)	25 (17%)	10 (7%)	26 (17%)	7 (4%)
TOTALS	189	1890	1089 (57,6%)	138 (7,3%)	250 (13,2%)	138 (7,3%)	204 (10,8%)	71 (3,8%

UNIFORM SLOPE QUESTIONS

AGE	SAMPLE SIZE	POSSIBLE ANSWERS	CORRECT ANSWERS	E6	E7
18	4	8	7 (88%)	0 (0%)	1 (12%)
17	20	40	30 (75%)	1 (2%)	9 (23%)
16	53	106	65 (61%)	8 (9%)	33 (30%)
15	55	110	64 (58%)	12 (11%)	34 (31%)
14	42	84	48 (57%)	12 (14%)	24 (29%)
13	15	30	18 (60%)	3 (10%)	9 (30%)
TOTALS	189	378	232 (61,3%)	36 (9,5%)	110 (29,2%)

Table 3.2. Results of contour interpretation tests.

Griffin and Lock reported that the most frequently selected error type was that of slope reversal (E2) and their finding has been reflected in the Kingswood study. To illustrate this point the total possible errors for each error type has to be calculated by subtracting the questions that did not give that optional answer from the total. The results are recorded below in Table 3.3.,

TOTALS		ERROR TYPES				
		E1	E2	E3	E4	E5
Total errors	801	138	250	138	204	71
Possible errors	7560	1701	1701	1323	1701	1134
Percentage	10,6%	8,1%	14,7%	10,4%	12,0%	6,3%

Table 3.3. The relative frequency of selection of error types (% of opportunities) by Kingswood pupils.

When comparing the results with the British study the Kingswood responses for each of the six educational categories recorded r significance values between 0,79 and 0,82 which gives a significantly different frequency of error at 0,02 (or 2%) level of confidence. Statistically this significance is tenuous but because the correlation is consistent with each comparison it can be concluded that the Kingswood study has shown much the same pattern. Griffin and Lock also found that the slope-reversal (E2) error was most frequently selected error at all educational levels. This point is reflected in the Kingswood study as shown in Table 3.4. below,

age	E2 responses	total errors	E2 % of total errors
18	6	13	46%
17	25	44	57%
16	59	186	32%
15	86	210	41%
14	48	162	30%
13	25	72	35%

Table 3.4. Slope-reversal error frequency.

The other pattern emphasised by Griffin and Lock is that errors were more prolific in questions that involved convex slopes. In the Kingswood experiment this same pattern was observed by analysing all the errors recorded for each of the slope type subsets and then calculating the observed total for each subset as a percentage of total possible error responses. The results indicate that errors involving convex slope are clearly more frequently made (Table 3.5.)

slope type	errors	number of questions	responses possible	%
convex	368	4	756	48,7
concave	425	6	1134	37,5
uniform	145	2	378	38,4

Table 3.5. Relative frequencies of errors in slope-type by slope type subsets.

(d) Comment on the experiment

Griffin and Lock concluded that the prime responsibility for the error patterns, with a focus on convex slopes and slope-reversal, lie with conceptual and perceptual problems inherent in the test. They pointed out that cognitive development together with continued experience would eliminate most traces of such conceptual errors. Thus the decline in error rates through the age sequence (Table 3.2.) is not unexpected. The perceptual problems are thought to be the effects of texture gradient and figure-ground effect so that Griffin and Lock focused the perceptual problems onto Gibson's (1950) texture gradient effect and Rubin's (1958) figure-ground effect.

Perceptual problems also underpin the experimental investigation that follows.

3.1.4. Experiment 4 (Contours and Labels)

(a) Model research study.

Phillips (1979) experimented in two ways with contour lines in order to test how altering the conventional contour line symbol and altering the altitude labelling convention would affect map-reading performances. For the first experiment Phillips tried re-arranging the altitude labels on contour patterns to test if the conventional method of orientation helped perception of the mapped landscape. He tested geography undergraduates and found that they were very poor at reading numerical values of an inverted label. He noted that the mental rotation interfered with the perception of the number's orientation.

For the second experiment he investigated a 'wedding cake' map (illustrated on page 40 of this thesis). His subjects had to try to visualize a small area of mapped landscape and indicate highest and lowest points on each of two maps, one a wedding cake map and one a contour map. Neither of the maps had altitude labels on them to indicate height. He found no significant difference between performances on the two different maps.

(b) The Kingswood experiment.

The perception tests were done in conjunction with the first experimental investigation reported in this chapter and the questions may be found in Appendix E.4.

For the first test eight circular contour patterns were used with altitude labels in eight different orientations. The subjects had to assess whether a point A inside the circle was higher than a point B outside the circle, or vice versa, or that they were the same height, or a fourth alternative 'I don't know'. Half of the labels appeared the right way round and half appeared upside-down because they show the direction in which the land slopes. The convention was explained carefully to all the subjects orally before the test was attempted and it could be found written at the top of the answer sheet.

For the second test Phillips' maps were copied exactly and a third map, a shadowed contour map (Tanaka, 1950 ; Yoeli, 1983), was added. Four points were marked in identical places on each map and the subjects had to assess which points were higher than others.

(c) Results of the Kingswood experiment.

The results of this test showed a similar pattern to the one reported by Phillips. The correct answers as a percentage of possible correct answers by each age group is illustrated in Table 3.6.

AGE	11	12	13	14	15	16	17
%	20	25	33	52	44	49	48

Table 3.6. Correct responses to contour labelling test shown as percentages.

The percentages are low with no real improvement from 14 years upward although it is clear that Junior School pupils had difficulty indicated by the nearly 20% improvement after the age of 13 years.

A total of 385 correct responses were recorded in the contour labelling test and unexpectedly 195 were with the label printed in upside down and 190 with it correctly orientated. It would appear that the orientation of the label, therefore played little part in correct decision making.

In the experiment that aimed to offer improved or easier conventions for height estimation, the results offer no clear pattern. They are shown below as numbers of responses that were correct as a percentage of possible correct responses for each age group.

AGE	CONVEN-TIONAL	SHADING	WEDDING CAKE
12	8	26	23
13	21	11	5
14	20	30	10
15	19	16	13
16	33	27	30
17	21	42	37

Table 3.7. Responses to height representation methods as percentages of possible correct responses.

No significant pattern or trend can be seen in these statistics even when they are illustrated in graph form as in Figure 3.5. over the page.

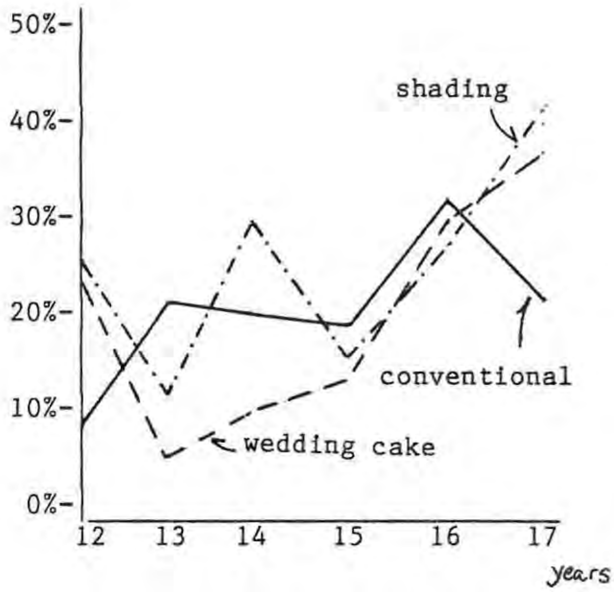


Figure 3.5. Graphic display of responses to height representation test.

The differences between contour and the other methods failed to reach statistical significance when analyses of variance were carried out and Chi squared tests also failed to reach significance. This suggests that there is little difference in performance between the three types of map.

(d) Comment on the Kingswood experiment.

Phillips reported that the orientation of the contour line label is not helpful to experienced map readers and the Kingswood experiment indicates that pupils at secondary school also find it difficult to extract two different types of information from a contour label : the numerical value and the orientation of the number.

In an attempt to offer improved designs of contour symbols it was found that there was no statistically significant difference between the methods employed. Elaboration, therefore does not appear to improve performance and the main problem of visualising relief from a contour map, the difficulty of integrating small areas of relief in order to visualise a larger area, remains.

3.1.5. Experiment 5 (Treasure Island).

(a) The model research study.

Piaget and Inhelder, (1956) devised a test to determine changes in children's views of perspective. They constructed a model of three different coloured mountains with each mountain being different not only in colour but also in size and in the features placed on it,

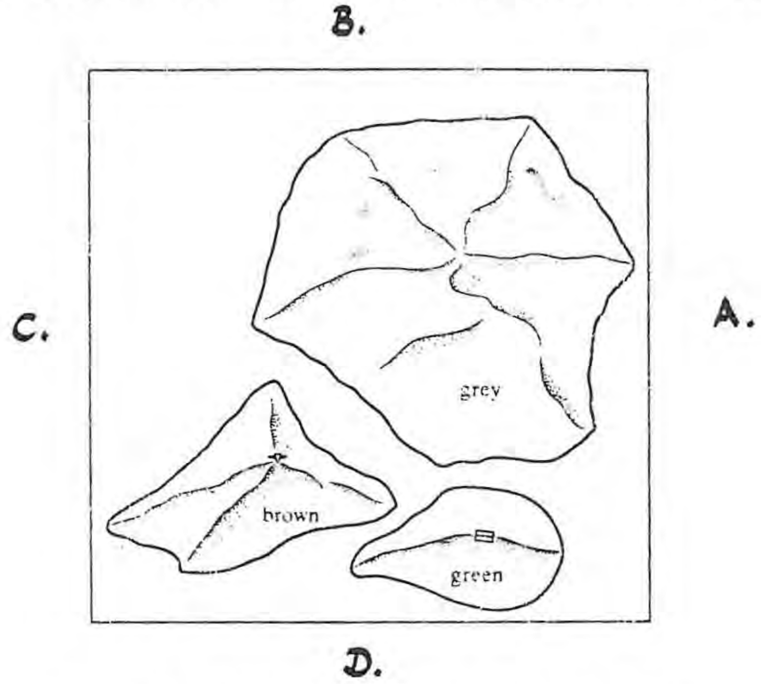


Figure 3.6. Piaget's Three Mountains Test.

Children were placed in front of the model at A and a doll was placed alternately at A, B, C and D. The children were asked to select from a set of pictures the view that best fitted that of the doll.

From the results of the test Piaget identified a continuous progression from the age of 9 years to 12 years during which the child becomes more proficient in the mastery of the perspectives involved. He claimed that by the age of 12 years the child should be able to separate itself from its own viewpoint and be able to reconstruct that of the doll. The child's viewpoint and that of the doll are now understood to be different. Piaget made certain statements such as "the perspective system which the child builds up in the course of the four sub-stages we have identified is not perceptual but conceptual in character" (Piaget, 1963, p.245).

(b) The Kingswood experiment

Piaget's idea of placing an object centrally and imagining side views from different perspectives has been extended in a test that replaces a solid three-dimensional model with a contour map-representation of an island, named 'Treasure Island', Four galleons, A, B, C and D marked offshore indicated the different perspective views (Appendix E.5.). Subjects were given an answer sheet with four columns of profiles marked A to D and each with five different alternatives for the subject to choose the closest fit to each imagined view.

The aim of the study was to see if any pattern would emerge in an extension of Piaget's experiment. The extension was from the concrete stage of thinking to the formal abstract level.

A sample of 215 pupils, (126 boys and 89 girls) was tested at Kingswood College. The test was carefully explained orally and the answer sheet had further instructions. A half an hour was allowed although no children took more than ten minutes to complete the exercise.

(c) Results of the Kingswood experiment

Age	Correct responses boys		Correct responses girls		Correct responses total	
	total	%	total	%	total	%
11	22	37	8	18	30	29
12	17	35	18	26	35	30
13	32	57	29	33	65	45
14	40	59	12	43	52	54
15	55	60	33	55	88	58
16	48	67	30	54	78	61
17	56	67	5	63	61	66
18	18	75	3	75	21	75

Table 3.8. Results of Treasure Island test of perspective.

Two main features have emerged from this experiment:

1. a gradual but consistent rise in correct response percentages from 29% for 11 year-olds to 75% for 18 year-olds, and

2. a difference in responses between boys and girls with the boys recording higher success responses than girls. A chi-square test was applied to the results to determine the significance of this difference statistically, (Appendix F.2.). The chi-square value of 36,0 for degrees of freedom = 7 indicated that the null hypothesis of no significant difference between the groups could be rejected at better than the 1% level of confidence. There is, therefore, a strong reason to believe that there is a significant difference between performances by boys and by girls.

(d) Comment on Kingswood experiment.

Piaget reported a continuous progression of proficiency by children with increasing age in his three mountains test and this pattern is reflected in the Treasure Island experiment. There is a steady increase in proficiency such that Piaget's conclusion can perhaps be extended and applied to the post 12 year-old age group with formal thinking, that is that the perspective system built up is conceptual and not perceptual.

Ballantyne (1980) noted a significant difference between the performances by boys and by girls in the Piaget three mountain test that he constructed in his investigation into spatial concept development in Natal primary schools. This trend is displayed as continuing at secondary school level. The differences in performance proficiency has been noted above as being statistically significant. To find the cause is beyond the scope of this study but it is of interest to note that a trend found by Piaget and later workers can be seen in the Treasure Island contour test.

Central to an investigation into the teaching and learning of three-dimensional graphicacy should be an assessment of the correlation between the ability to think abstractly in three-dimensions and to perform well in contour mapwork. However, there is no published research investigation that aims to test this relationship and that can be used as a model study. Therefore, a combination of several experimental studies has been tentatively used to prepare an exercise that investigates a range of mental procedures with contour maps and with non-related structures. The final test construction aims to test the null hypothesis that there is no significant correlation between three-dimensional thinking ability and contour mapwork performance.

3.1.6. Experiment 6 (Contours and Cubes)

(a) The model research investigation.

Cooper and Shepard (1984) designed experiments to probe the process of spatial imagination. The subjects of their experiments compared computer-generated perspective line drawings presented in pairs. Each drawing portrayed a three-dimensional object composed of 10 cubical blocks joined face to face to form an armlike structure exhibiting three right-angled bends, (Figure 3.7.).

Figure 3.7. Perspective views of sample structures used by Cooper and Shepard, (1984) to investigate spatial imagination.

The subjects then decided whether the structures were identical or different in some way. Because the pairs of drawings represented objects that either were identical or differed by a reflection in space, the subjects could not base their comparison on superficial features of their stimuli. The differences were presented in three ways; a rotation within the plane of the picture, a rotation in depth, and enantiomorphic or mirror-image shapes. The experimenters claimed that short-cut searches for obvious differences was ruled out and that subjects could compare the shapes only by imagining one of the two objects rotated into the same orientation as the other and then checking for a match.

(b) The Kingswood experiment.

Cooper and Shepard's experiments form the first part of this exploratory pilot study which attempts to correlate three-dimensional thinking ability with contour mapping proficiency. Five pairs of structures have been copied and they make up the first five items in the part of the test which attempts to gauge the ability of subjects to twist objects abstractly in their minds and thereby to 'think three-dimensionally', (Appendix E.5.)

The second part of the test into spatial imagination was copied from some of the mathematical spatial visualization exerises prepared by Lappan et al (1984). Lappan indicated that most of a student's mathematical experience with the three-dimensional world is obtained from two-dimensional pictures and yet many students cannot 'read' these two-dimensional pictures well enough to determine needed information about the solid objects. This assertion has been tested with items 6 and 7 of the test which are representations of solid shapes made up of cube block components. Pupils were asked to assess how many cubes were incorporated into each structure. To answer correctly they had to be able to visualize the hidden corners of the solids and this tested their ability to 'read' this information and thereby to think three-dimensionally from two-dimensional stimuli.

The remaining items in this part of the experimental testing of three-dimensional graphicacy required pupils to not only read but also to represent information about the real world with two-dimensional pictures. Again cube-blocks have been used as the basic units because of their flexibility and the pupils were required to imagine units being removed from, and then added to, different structures and then attempt to represent what they considered the altered structure would look like.

The first part of the exercise therefore attempted to test a range of abilities including three-dimensional rotation of objects in the mind, reading three-dimensional concepts from two-dimensional images and finally drawing on a two-dimensional plane from a three-dimensional mental image. Altogether the different items were considered to be a suitable combination with which to test 'three-dimensional thinking' skills within a reasonably short period of time in a class-room situation.

The second part of the experiment attempted to test the visual-spatial ability of the same pupils in the context of contour map-reading abilities. Underwood's (1981) study was used as the model as it appeared to present a satisfactory range of three-dimensional perception tasks. These included assessing the pupil's ability to judge relative heights, to estimate heights from the map symbols, to interpret the shape of the land by drawing in rivers and by locating steep and gentle slopes, to visualize the landscape by mentally assessing the intervisibility of points, and finally, his ability to rotate the image of the landscape displayed by the map through ninety degrees so as to match up profile views.

Administering the tests.

Altogether 270 pupils aged from 10 to 18 years, all at Kingswood College were tested as an available convenience sample. The sampling method is the biggest threat to the external validity of the test because it cannot be considered to be representative of a wider population. One particular reason for this is the socio-economic background differences between Private School children and the wider population. One severe check to the internal validity of the test is that no account has been taken of the fact that the pupils in the Junior School part of the sample had received no tuition in contour mapwork, while the Senior College pupils had had an introduction at the Standard 6 level. This dichotomy cuts across the 12/13 year age groups so that the results of the experimental tests at this level must be considered to be of questionable significance, and this point is dicussed later.

The pupils were tested in the classroom during a convenient lesson period of forty minutes by the researcher, and instructions were given verbally as well as being printed on the test sheets. Questions related to the instructions were answered verbally and although the situation appeared to be potentially stressfull, pupils were relaxed by the knowledge that 'marks' were not going to be recorded against names.The tests were performed anonymously in that each sheet had a block at the top within which the pupil could put an individual mark so that the sheets could be compared later.

(c) Results of the Kingswood experiments.

A number of statistical tests were applied to investigate the possible correlation between the three-dimensional thinking tests and the mapwork proficiency tests at the different ages, and a summary of the results is recorded in Appendix F.3. An overall statistical calculation, using the Pearson product-moment correlation coefficient test for the 270 pupils tested, produced an r value of 0,65 which gave a t value of 14,03 which was well to the right of Fisher's Table of t for the sample size. This was taken to mean that there is a significant statistical correlation between the overall responses to the three-dimensional cube tests and the map proficiency test and the null hypothesis was rejected at less than the 1% level of confidence.

(d) Comment on the Kingswood experiment.

Several significant features emerge from these results and these are itemized below :

a. The sample sizes of four 18 year-olds and six 10 year-olds are too small for any statistical significance to be paid to these age groups.

b. The sample tested both children who had received tuition in contour mapwork and those who had not. The mean score dropped from 14 for 17 year-olds (61%) to 4 for 12 year-olds (17%) with a clear drop from 11 (47%) to 7 (30%) between the ages of 14 and 13. This clearly marks the boundary line between those who had received tuition and those who had not.

c. The mean scores for the three-dimensional cubes tests showed a similar dichotomy but this cannot be attributed to tuition. The mean score ranged from 10 for 17 year-olds (77%) to 5 for 11 and 12 year-olds (37%).

These trends can be best presented in graphic form :

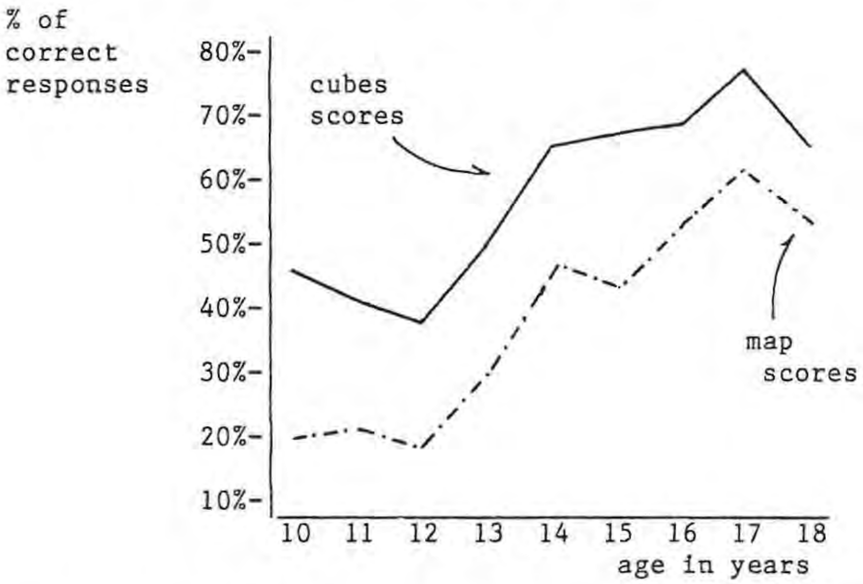


Figure 3.8. Graph of correct responses to the cubes tests of three-dimensional thinking and the mapwork proficiency test.

d. The correlation coefficient or r scores calculated for each age group were significantly positive for the age groups above 14 years where tuition in mapwork had been received. Below this age no significant correlation is seen, as r scores range unpredictably from negative to nearly zero values.

The experiment tentatively suggests that there is a positive correlation between ability to think three-dimensionally, as tested by a series of cube block tests, and to perform effectively in contour mapwork skills.

This relationship is claimed despite the lack of standardisation in the testing methods and scoring, and despite the fact that the tests were applied to children of very different mapwork backgrounds. Despite the many weaknesses in the test structure, the positive correlation as tested appeared to be significantly positive.

In order to test the hypothesis, that a pupil's contour mapwork proficiency is inexorably linked with an ability to perform abstract thinking tasks that imply conceptual understanding of the third dimension from two-dimensional images, a further simple test was devised that used only three responses and thereby perhaps tests this relationship more directly.

3.1.7. Experiment 7 (Rubik cube and Profiles)

(a) The model research study

No exemplar or model study was used for this experiment. It was devised with an aim of reinforcing the findings of the previous experimental testing because the previous test pointed towards a positive relationship between mapwork performance and three-dimensional thinking but had too many variables within its structure.

(b) The Kingswood experiment.

212 pupils were tested individually and each was presented with three cards, (Figure 3.9.), one at a time. After each assessment the researcher asked, in an interview situation, a reason for that choice.

Card 1 was a colour image of a 'Rubik' cube with a corner block missing viewed from obliquely below this corner. The card showed four small blocks numbered one to four and the pupil responded by indicating which was the missing block.

Card 2 showed a simple profile and four numbered contours and the pupil assessed the matching contour.

Card 3 showed a contour pattern and four profiles for the pupil to match up.

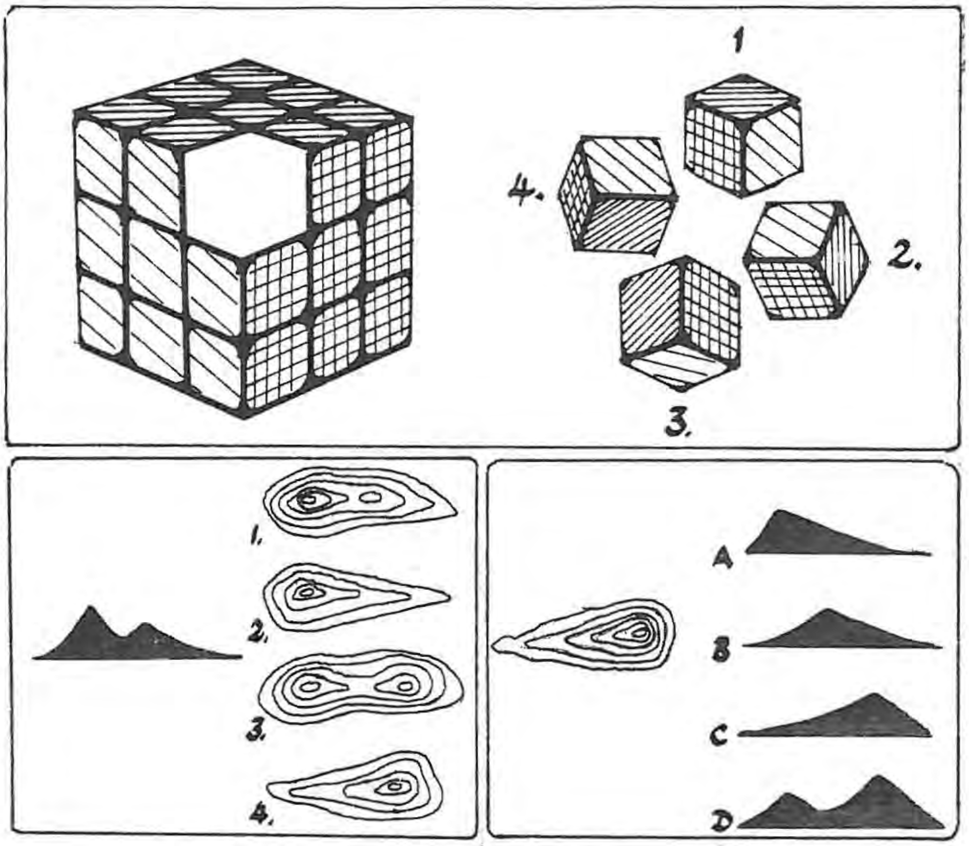


Figure 3.9. Test items for Experiment 7 (Rubik Cube and Profiles)

(c) Results of the Kingswood experiment.

The responses were grouped according to the age of the respondents and a chi-square test was applied to examine if there was any significant difference between the performance of the pupils on the three tasks (Appendix F.4.). The test indicated that there were no significant differences.

With the Pearson product-moment method the correlation between the Rubik Cube card and each of the contour/profile cards was tested. The null hypothesis tested was that there was a significant difference between the responses to the Rubik cube card test and responses to the profile/contours and the contour/profiles tests.

The results of each test were :

1. Rubik Cube Card 1 and Profile/contours Card 2.
   The r value was 0,94 which gave a t value of 6,17 and allowed the null hypothesis to be rejected at <1% level of confidence.

2. Rubik Cube Card 2 and Contour/profiles Card 3.
   The r value was 0,89 which gave a t value of 4,33 and allowed the null hypothesis to be tenatively rejected at between the 1% and 2% levels of confidence.

3. Profile/contours Card 2 and Contour/profiles Card 3.
   The r value was 0,96 which gave a t value of 7,68 and signified a very close correlation between the responses to these two tests.

Shown graphically (Figure 3.10.) as percentages of correct respondents, the pattern that emerges is very similar to the pattern of correct responses found in Experiment 6 (Contours and Cubes). One may, therefore, draw the conclusion that, as tested, there is a close resemblance in the performances of children of the same age groups in the two experiments.

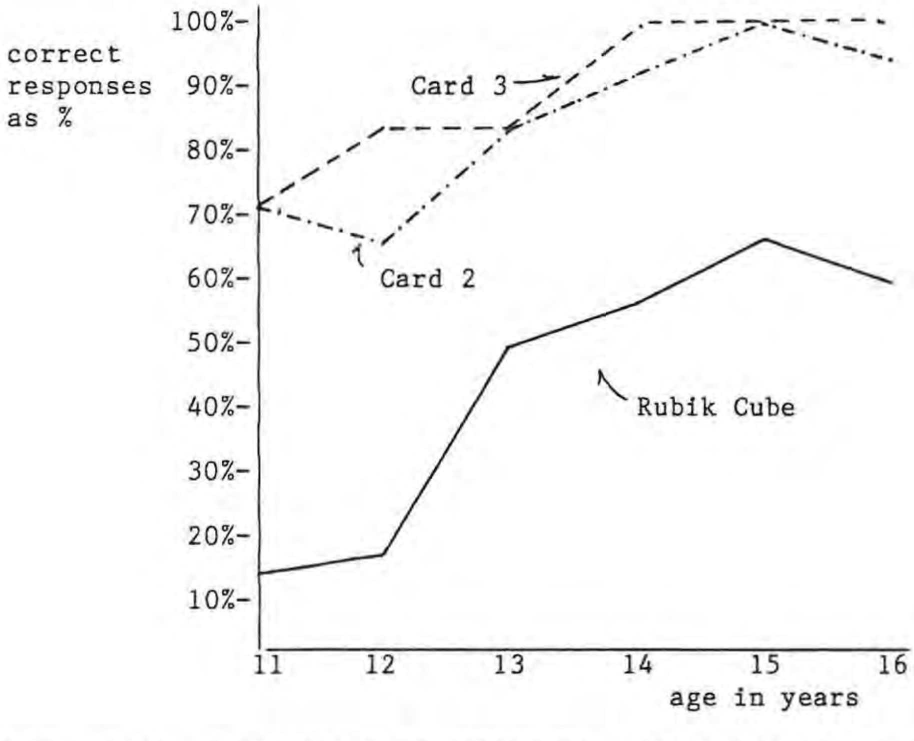


Figure 3.10. Correct responses of pupils to Experiment 7 shown as percentages of total possible correct responses for each age group.

(d) Comment on the Kingswood experiment.

The results of this experiment appear to reinforce the findings of Experiment 6 which suggest that there is a close correlation between the ability to think three-dimensionally from a two dimensional image and the ability to perform well in a contour mapwork exercise.

An important observation is that many children, who had not received any tuition in contour mapwork, were able to accurately match the contours with the profiles. Typical answers as to why the correct responses had been gauged include indications that they could read the contour circles as high points, 'two mountains', 'a big one here and a small one here' and one 11 year-old even pointed out that there were two 'peaks' on the map.

CHAPTER 4

RECOMMENDED SOLUTIONS TO THE PROBLEM OF POOR CONTOUR MAPWORK PERFORMANCE.

4.1. REDEFINITION OF THE PROBLEMS AND INTRODUCTION TO THE STRATEGIES FOR SOLVING THEM.

Pupils in South African secondary schooling appear to be performing badly in three-dimensional mapwork. This is reported regularly by examiners and by teachers, and the problem appears to be symptomatic of a universal pattern reported succinctly by Carswell (1971, p.42). His views are quoted fully below because they pinpoint the problems.

> "I think that there at least four reasons, and probably many more why the educational system has performed so inadequately in teaching map reading skills.
> First, I suspect that there is a gross oversimplification in the minds of teachers of just what is involved in reading a map. After all a map is an extremely complicated combination of lines, colours, and symbols, in which reality has been transformed in terms of scale, shape and perspective.
> Secondly, I suspect that wrong things are being taught about maps. That is, teachers are probably teaching about maps rather than with maps.
> Third, I suspect that there is something lacking in the sequencing of map skills.
> Fourthly, the techniques which are used to introduce mapping skills seem to be ineffectual, if they exist all. In many cases, the teacher seems to assume that children can read a map."

This section of the thesis attempts to remedy this reported malady. Carswell indicates above, that teachers misjudge the skills involved and an attempt to address this problem is met with a structured list of skills. Carswell then notes that wrong things are sometimes taught, and this is met with a consideration of what is misunderstood and misconceived. To meet his third problem of a lack of sequencing map skills, a scheme of work is presented. Finally to meet his fourth challenge, that techniques of teaching are ineffectual, a Teacher Guide has been prepared. Conclusions are then drawn, and recommendations made for improving graphicacy in South African secondary schools.

4.1.1. A structured list of skills : an answer to the question of, 'what are the appropriate skills?'

In this section an attempt is made to list the main skills involved in contour mapwork in a sequential developmental order. It is not a list that explains how to present the information to develop the skill, but the recommendation is that it should be used as a check-list guide.

At the concrete stage of thinking children can be introduced to three-dimensional representation of relief by using models. Models imply a process of miniaturising or reducing in scale a three-dimensional reality to a three-dimensional representation of that reality. Pupils at the concrete stage of thinking are able to cope with reduction in scale, (Piaget, 1956) as their play experience from early childhood has usually involved miniaturising real objects. Children regularly play with a miniature world and the transition from real to reduced does not require higher order thinking abilities or concept acquirement beyond their stage of development that a two-dimensional map view implies.

Pupils should participate in the construction of the model and there is a wide variety of modelling approaches available to teachers. Contours should be marked on the landscape models and there is a wide variety of methods to do this. From contour modelling pupils learn the following concepts :

a. Contour lines are always horizontal and perpendicular to the dip of the land.
b. All contour lines are closed lines, unless cut off by the margins of the model.
c. From a bird's eye view the model shows that the steeper the slope the closer the contour appear.
d. Valleys have contour lines pointing upslope while spurs point down.
e. Contours are evenly spaced vertically - the contour interval.
f. Contours are not terraces and the slope does not alter at each contour line. Contour lines are, therefore, not boundary lines.

From the stage of constructing models pupils at the formal stage of thinking should move to the simple reading information skills. Reading the 'language' of the contour map includes :

a. Reading altitude or heights from the symbols displayed. These include trignometrical beacon heights, bench mark heights, spot heights and crossed by contour lines.
b. Estimating highest and lowest points on the map.
c. Learning the convention of the vertical interval.

The next skill to be developed should be the skill of translation. This requires translating from one form of information to another. The skills of this type to be developed include:

a. Estimating the altitude of points that are located between contours by assessing the proportional distances between contour lines.
b. Interpolation whereby a map with spot heights on it is presented to the pupil and his task is to draw contour lines. These can be graded in difficulty from a very simple point to point line,to a partially completed map, and finally to map with no contours to complete by drawing lines proportionally distanced between the spot heights.
c. Slope shape recognition. This should build up from understanding that contour spacing indicates steep or gentle slope, to understanding regular, concave, and convex slope shapes.
d. Recognising landforms from contour patterns. These should build up from simple to more complex patterns. It is a method preferred by all the secondary text books but a warning by Board and Taylor (1977) that there are dangers of teaching mapwork by example as developed by Dury because the 'vocabulary is extremely complex', must be noted.

An important skill, and one that is regularly evaluated in examinations is the skill of profile construction. This implies an ability to understand the mental rotating from overhead view to side view of the landscape, an abstract twist of ninety degrees. The construction of a profile involves a variety of skills. These include:

a. measuring the horizontal distance on the map,
b. recording the vertical rises and dips and features crossed by the section line on a recording paper,
c. construction of a framework with an assessment of an appropriate vertical scale,
d. transposing recorded point information onto the profile framework, and
e. translating it into a profile line.

From this construction a number of skills are required in its translation and these include :

a. Placing detail on the profile by finding the information on the map and placing it accurately on the profile surface.
b. Intervisibility between points which can be gauged by a straight line between the points on the profile.
c. A thalweg or irregular profile along a valley increases the skills required in profile construction to include the recording of slope change along a meandering line.

Further skills developed from profile construction include measurement and calculation. These comprise :

a. An overland distance measurement that requires the measurement of distance up slope and down slope as opposed to the horizontal distance which implies that the land is perfectly horizontal.
b. Calculating gradient requires measurement of horizontal distance between two points, calculating the vertical difference between the two points and then by using the formula,

$$\text{GRADIENT} = \frac{\text{HORIZONTAL DISTANCE}}{\text{VERTICAL RISE}}$$

calculate the gradient.

c. Vertical exaggeration. This is a necessary component of depiction of relief in side-view because it is a part of human nature that we are more sensitive to the up and down of the land than we are to its horizontal measure. If a profile of the land is drawn to the same scale vertically as horizontally, it looks incredibly flat. To bring out the ups and downs to correspond better with our mental concept, the vertical component has to be exaggerated. The degree of exaggeration depends on the scale, on the nature of the landscape and on the purpose of the profile. The skills involved in calculating a vertical exaggeration, relating the horizontal scale to the vertical scale are mainly mathematical.

Visualisation of the three-dimensional landscape from a map representation requires a higher order skill; that of interpretation. The pupil is required to form an image in his mind of the gestalt or whole, by disregarding visual noise and by perceiving embedded shapes. From this he may be required to analyse, synthesise and even evaluate the landscape. Clearly this skill can only be introduced at the end of a pupil's secondary education. Interpretation skills include :

a. Relating flow lines to contour patterns. Communications lines usually reveal a clear relationship with the relief of a region. Roads and railway lines seek valleys in mountainous terrain, and seek watersheds on flatter landscapes, and the discerning pupils can visualise these relationships.
b. Drawing in rivers on a contour map is a similar skill that requires the pupils to be able to recognise valley-forms.
c. Demarcating relief regions. This skill involves the ability to recognise differences in landscape type in different parts of the map, and to mark in the boundaries between each.
d. Indicating watersheds and defining river basins is a similar skill that requires the pupil to be able to visualise the landscape in order to differentiate.

e. Comparing relief patterns with man-made patterns requires the pupil to relate the man-made pattern to a recognisable relief feature or landform type. An example is the relationship between the site of a town, or of a dam, or farmstead and the landscape or the broader patterns of cultivation, forestry or other land-uses with relief.

It is perhaps useful to present a summarised list of the skills recommended in table form:

SKILL TYPE	SKILLS INVOLVED
MODELLING	Construct a three-dimensional model
READING	Read altitude from symbols Estimate highest and lowest points Vertical interval
TRANSLATING	Estimating heights between contours Interpolation Slope shape recognition Landform recognition from contours
ROTATING	Profile construction Placing information on the profile Intervisibility Thalweg or irregular profile
MEASURING & CALCULATING	Overland distance Gradient or slope calculation Vertical exaggeration
INTERPRETING	Relating flow lines to contours Drawing in rivers on a contour map Demarcating relief regions Marking watersheds and river basins Relating man-made and relief patterns

Table 4.1. Summary list of recommended three-dimensional graphicacy skills.

4.1.2 Evaluating mapwork skills.

Examiners need to consider Earle's (1975), recommendations for better evaluation of mapwork papers. The list presented here as Table 4.1. is tentatively offered as a framework for constructing a specification table such as the one Earle suggests.

4.1.3. Misconceptions and misunderstandings.

If teaching is to be effective, knowledge of the students' conceptual abilities and previous knowledge is essential (Helm, 1978). Problems in learning often arise due to :

(a) An inadequate cognitive level to comprehend a concept fully.
(b) A lack of teacher awareness of the students' conceptual abilities.
(c) Misconceptions or misunderstandings in the student's previous knowledge which prevents comprehension.
(d) Unclear presentation in teacher-instruction and text-books and even misconceptions held by teachers (Helm, 1978; Giannangelo and Frazee, 1977).

These four learning problems may form the origins of the resultant misunderstandings and misconceptions. (Welch, 1981). For effective teaching then, it is important to be aware of possible misunderstandings or misconceptions, to trace their origins. The difference between the terms misconception and misunderstanding needs to be established. Misconception refers to erroneous notions which are held by groups or individuals, (Za'rour, 1975). Misunderstanding refers to erroneous notions which are neither commonly held nor identical amongst individuals. Commonly made errors include :

a. That contours are boundary lines or step-ups from one flat layer to another higher level. To overcome this problem teachers should make it clear in a layered model that pupils fill the landscape between the contour edges.
b. Classic contour patterns for landforms lead to many misunderstandings especially when children try to learn the shapes off by heart.
c. The misconception that high land is steep land.
d. In the measuring and calculating skills there is often confusion between the concepts of vertical exaggeration and slope gradient.
e. In the construction of a profile there is often a misunderstanding of the projection of land below the two lowest recorded contours in a valley and above the two highest in a peak.

By being conscious of these common errors, the teacher can take measures to negate the problems. They are errors that usually creep in when concepts that are beyond the mental development range of the pupils are introduced too soon and without proper sequencing.

4.1.4. A scheme of work : an answer to the question of when to introduce skills.

A simple scheme has been devised which attempts to divide contour mapwork teaching into four stages. These stages relate to a pupil's conceptual development through school. The list is intended to be a scheme of work guide and although methods of introducing concepts are referred to it is not the purpose of this section to expand on methods as these will be considered in the next section of the thesis.

Stage 1 - Model making.

In the transition period between junior and senior schools, when pupils are eleven or twelve years old, most are in the transition period between concrete and formal levels of thinking. In recognition of this, some private preparatory schools continue 'primary' education through Standard 6. It is therefore considered a valuable preparation to three-dimensional graphicacy, that pupils at this stage should restrict their three-dimensional mapwork to work with three-dimensional models. This would appear to be consistent with the thinking of Piaget (1958), Bruner (1960) and Rhys (1972) discussed in Chapter 5.1. of this thesis.

Stage 2 - Reality orientated.

Work in the junior secondary schooling has two main aims. The first is to prepare pupils who wish to continue with geography as a senior examination subject for later skills, and the second is to provide those who do not wish to continue with geography, with a worthwhile graphicacy background. For these reasons stage two relates to pupils aged thirteen and fourteen in Standards 6 and 7. The recommendation is that work in the third-dimension should be restricted to reality orientated studies. Pupils should do all their three-dimensional graphicacy in the field. A number of exercises can be introduced such as field sketching and orienteering. Realistic representation is given in film and video-tape productions which are available to most schools, and computers offer future potential at this stage of schooling.

Stage 3. - Abstract skills.

At this stage it is assumed that most pupils have reached a formal stage of thinking and therefore it is recommended that mapwork should focus on map sheet skills. The theory section of the Standard 8 syllabus focuses on geomorphology so that it is appropriate that three-dimensional mapwork should include recognition of landforms and slopes and construction of side profiles so as to reinforce landscape analysis. Pupils should be exposed to 1:50 000 maps and map extracts often as experience and proficiency builds up with constant practice.

Stage 4. - Interpretive stage.

In the final years of secondary schooling pupils should work towards visualising landscapes as wholes, or regions and exercises should require them to interpret relationships between landscape and human patterns.

AGE	STAGE & CLASS	SKILLS
11 / 12	Std. 5 and 6 STAGE 1.	MODEL MAKING Model construction and interpreting.
13 / 14	Std. 6 and 7 STAGE 2.	REALITY ORIENTATED Work in the field including field sketching and orienteering. Film and video presentations. Computer assisted learning
=====	================	==================================
15 / 16	Std. 8 and 9 STAGE 3.	ABSTRACT Map translation including slope shape and landform recognition. Profiles construction and skills. Calculation of gradients etc.
17 / 18	Std. 9 and 10 STAGE 4.	INTERPRETIVE Landscape visualisation exerises including interpreting relationships between relief and man-made features and patterns.

Table 4.2. Summary scheme of work for introducing three-dimensional graphicacy.

The Table is divided into two separate blocks by the heavier line across the centre and this represents the stage that pupils choose the subject for higher study for matriculation examinations.

One important principle related to the above scheme is that pupils should 're-visit' regularly the skills of the previous year, as recommended by Bruner, so as to reinforce learning.

4.1.5. A Teacher Guide : an answer to the question of how to introduce the skills.

It is intended that the recommendations listed below should be considered in conjunction with the lists of the previous sections of this Chapter of the thesis. The method for teaching a concept chosen from the list below should be considered in relation to the pupil's stage of schooling.

4.1.3.1. Models

Modelling landscapes can be done in a variety of ways and can be as simple as shaping sand or earth on a playing field and as complex as intricate polystyrene modelling. The list below starts with those models that the researcher has found to be most successful when teaching pupils in the transition Standard 5/6 stage. Not only do they understand the concepts but they are very motivated to model at this age (the age of the electric train and balsa model!)

a. Glass model
This is a most effective and rapidly produced method of introducing contours. The model has the advantage of having an overhead view which gives a clear impression of a map while an oblique view provides an illusion of relief. If the glass is marked with washable ink different map/models can be rapidly prepared. Pupils can easily make their own models as the only skill required is the skill of tracing contours onto the glass. Another advantage is that all that is needed to prepare this model is six or seven small panes of glass, some corner ledges (erasers work well), and a felt-tipped pen of the type used on overhead projectors. The model is flexible and very easily stored. Hurry (1978, p.126) suggests a glass model for teaching contours but his method is to place each pane of glass on top of another. The effect is not nearly as spectacular or effective as when the sheets are separated. A sketch diagram of such a model is drawn below.

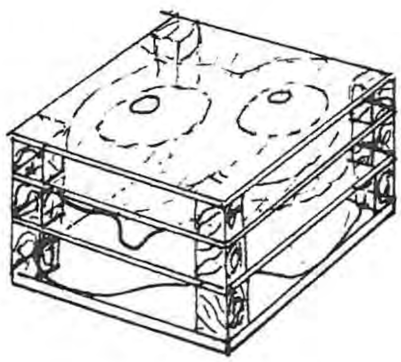


Figure 4.1. A glass model of a contour map.

b. Polystyrene model

Munowenyu (1985) illustrated how a simple relief model can be made by using kaylite (expanded polystyrene). What he neglected to realise is how easy this material is to shape with heat, as it melts very easily, and his method of cutting with scissors has an unfortunate effect of pinching the edges. Polystyrene sheets provide a very versatile material that has many advantages for modelling. These are listed below:

- The material is very easily cut. Hot wires can be made with varying degrees of sophistication (Figure 4.2.). The simplest is a sewing needle attached to a wooden handle (a pencil) which is dabbed into a candle flame. However, the needle soon loses heat and needs constant dabbing into the flame. Small battery operated wire cutters are commercially produced and can be used in much the same way as a small fret-saw. The advantage of this type of cutter is that the wire stays hot while it is switched on. The most sophisticated commercially made cutter is electric, has a wooden base, has temperature control and is much bigger.
- The material is extremely light and manageable, which is a decided advantage over earlier traditional modelling materials.
- Polystyrene is produced in sheets of varying width so that contour intervals can be made to vary with ease.
- The material is very easily joined together with a PVA glue.
- Polystyrene is very easily painted with water base paints which can give a very realistic and artistic appearance.
- Polyfilla can be used to smooth out the landscape between the polystyrene sheet steps.

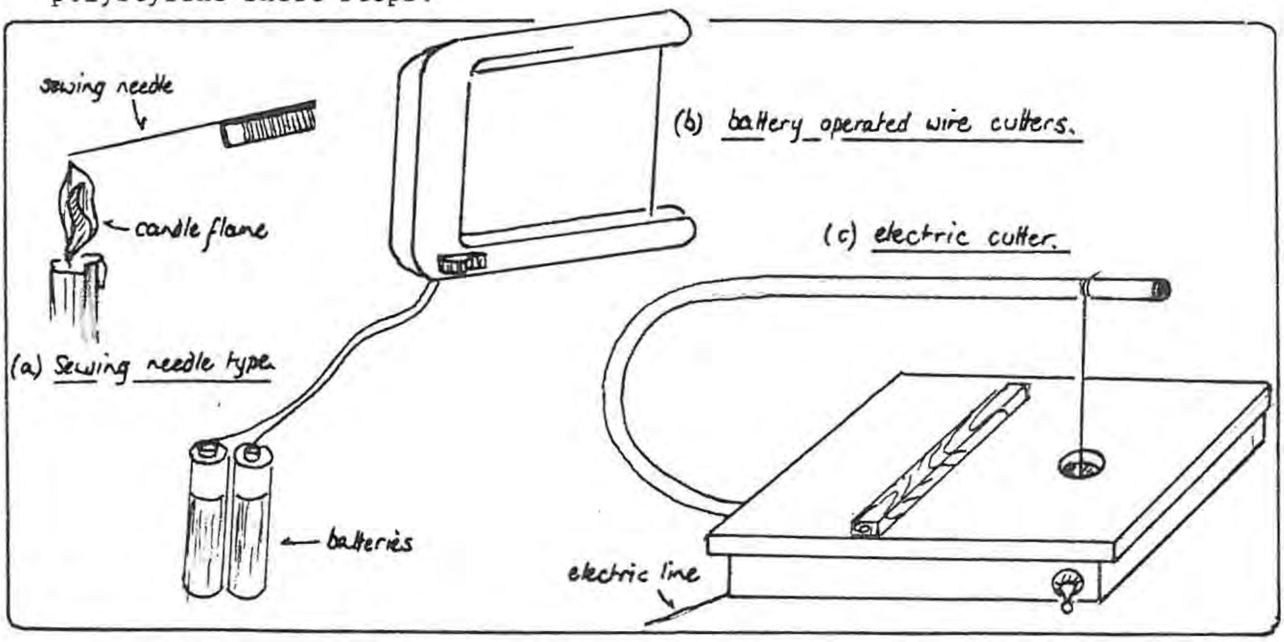


Figure 4.2. Hot-wire cutters used for shaping polystyrene.

c. Overhead projector model.
King (1982) suggested a novel, and very simple transparent three-dimensional island or hill, (Figure 4.3.) on which contours have been drawn which can thereby be projected onto a screen as a map view. This simple model can be used to teach, by direct viewing, that contours are lines of equal height, that they are continuous, that they are drawn at fixed intervals, when they are close together they indicate a steep slope and when far apart a gentle slope and a cross-section shows contours as parallel horizontal lines.

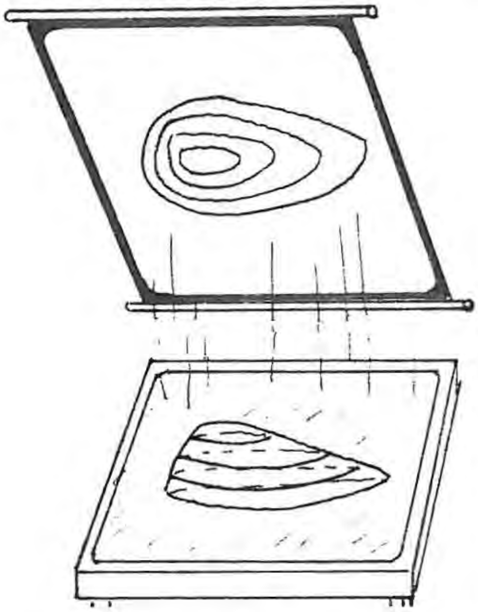


Figure 4.3. Acetate model for use on an overhead projector.

d. Tank models.
A very effective way of introducing contours as levels is to use the natural top level of a liquid. If water is added or removed the new level can be marked on the model (Figure 4.4.).

Figure 4.4. A water tank model.

e. Wet sand model.

Hurry (1978, p48) illustrates a very simple and very effective method of introducing contours by using wet sand (Figure 4.5.). The teacher places marbles or bottle tops along a horizontal plane, watched by the class, and they then view the model from above after the marbles have had a line marked between them.

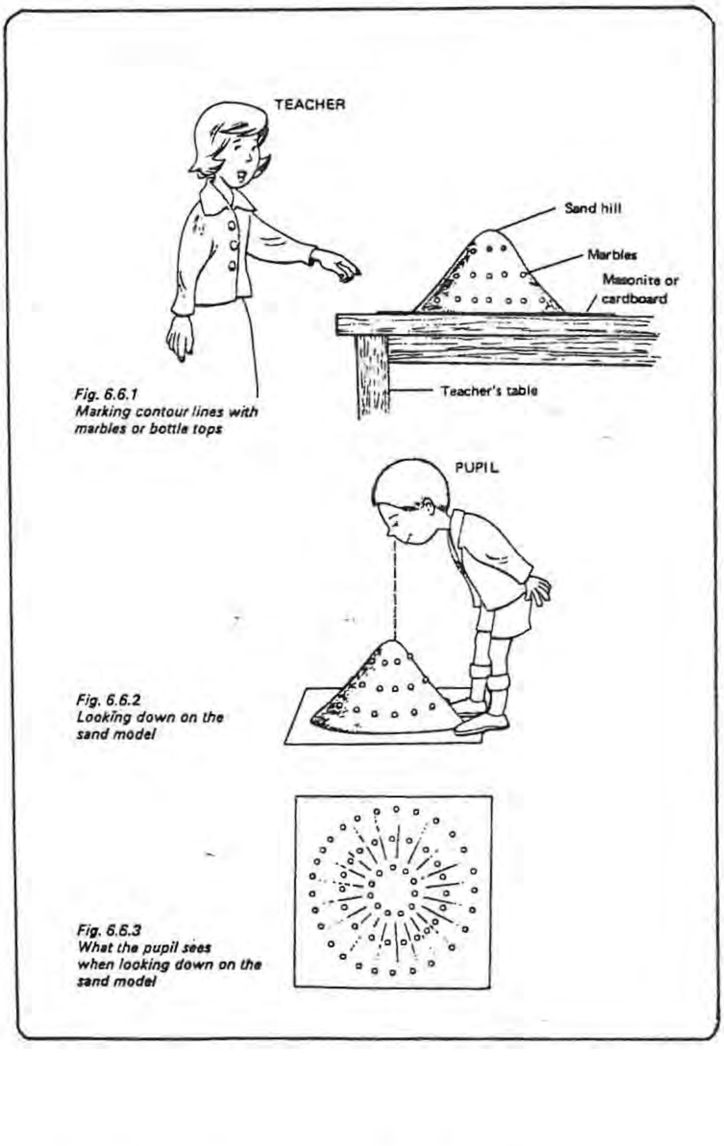


Figure 4.5. Wet sand model for teaching contours.

f. Other models

A variety of materials can be used to make other models and they are well documented. Boardman (1983) describes models using plasticine (which is cheap, quickly moulded and waterproof) acetate, and expanded polystyrene ceiling tiles. Hurry (1978), has novel ideas using glass headed pins with cardboard, masonite, plaster of paris, papier-mache and glass models. Sutcliffe's (1983), novel suggestion of constructing a hexagon shape board with holes and dowelling to act as a moulding 'template' is a very helpful and effective one. King (1985) has interesting ideas on paper constructions. Bailey (1978), provides a useful summary of the more traditional methods of building models using such materials as chicken wire to make the frame.

Model making has the element of 'play' that makes it attractive to pupils, and therefore a very valuable method of starting a three-dimensional graphicacy course. From the world of make-believe the next step should be the step to reality. Garnett (1960) warns that a model is always artificial and if models are to work they should relate to country that is local and familiar to the pupils.

4.1.3.2. Fieldwork

It is important for pupils to understand that contours represent real landscape. The exercises suggested below should help to substantiate perspective.

a. Appreciation of vertical scale.

This can be gained in any area that has relief. If the teacher hikes with the the pupils up a 100 metre hill and then presents the map for the first time at the top of the hill and asks the pupils to locate their position, the predictable expectation is one of many contours to mark the journey. Pupils are inevitably surprised to see how few contours they have crossed, and get a first-class impression of the scale involved.

b. Orienteering.

This introduces the element of competition and is a very valuable method of exposing pupils of thirteen and fourteen to a practical experience of scale, distance and the vertical element of the mapped landscape (Pirie, 1968; Disley, 1972)

c. Landscape field sketching.

By making pupils sit and attempt to draw panoramic view the teacher is leading them to visualise the vertical element in the landscape. Features such as spurs and valleys are recognised and recorded by simple outlines and if this skill is reinforced by referring to the map of the area and identifying these features on the map, the pupils' perception of the three-dimensional component of graphicacy is enhanced immeasurably (Burton, 1974).

d. The human contour.

Long and Roberson (1966) suggest an interesting field exercise whereby pupils align themselves along a contour and record and mark heights on the land. This 'human contour' shows that contours are not visible on the ground and that the shape depends on the configuration of the ground. Pupils learn that contours have shape and if several contours can be recorded aspects of vertical interval will be learned.

Riffel (1969) emphasises the value of fieldwork in contour learning, as a field trip helps the child understand that geography deals with the reality of the earth and 'anything he learns from it has real significance'.

4.1.3.3. Depth points.

Garnett (1960), and Long and Roberson (1966) claim that an inverted view of relief helps pupils to visualise contours. The first step in using this method with younger pupils is to get them to stand in a small pond or depression and record points where ankle or knee contours are recorded. A rule could be used and spot heights linked up to a map of the pond. The advantages of this method are that it allows easy reference to a level as a base from which to measure that is present in all parts of the pond, and it is a situation that a pupil finds easy to imagine.

4.1.3.4. Interpolation.

Perhaps the first abstract contour exercise should be the practical exercise of recording contours by interpolation. This skill could be introduced in three stages :

a. Linking points that have the same spot heights.
b. Completing a partially completed contour.map.
c. Preparing a contour map from a sheet where spot heights alone are given.

This method of teaching contour work has the advantage of making pupils aware of contour patterns and properties, such as that hills have concentric patterns, that contours never cross each other, and that the altitude of points between contours can be estimated by proportion.

4.1.3.5. Films and video tapes.

Films have the advantage of being able to represent reality and to bring it into the classroom situation. Oblique and overhead views as well as side views can be explained with clear imagery. There is one particularly good presentation available to schools in South Africa, Map Reading: Relief produced in colour 1976 by the National Film Board. It is a thirteen minute presentation.

4.1.3.6. Computer assisted learning.

This aid is still in its infancy but already there are a number of commercially produced programmes. The computer has the advantage of a one-to-one learning situation (Shepherd, Cooper and Walker, 1980; Monmonier 1982; Kent, 1983; Midgely and Walker, 1985) and the important ninety degree rotation from over-head map view, through oblique view to profile side view can be performed by the pupil, thereby reinforcing the relationship between the vertical and the horizontal perspectives. Some of the available programmes are:

a. Contour (BBC B : Grange Software) which draws a cross section through the map drawn on the screen by the user with a joystick.
b. Contour (Apple: Longman) where contour interpretation is related to cross-sections and three-dimensional aerial views of the landscape. The teacher is able to introduce new maps in this programme and it also provides the facility of drawing cross-sections using a joystick.
c. Contour Plotter (BBC B) plots a contour map based on co-ordinates and heights of points.
d. Contours (RML : Heinemann) contains 54 geographical features which can be selected and then the feature may be viewed from any direction and cross-sections taken.
e. Profile (MEP) explores the relationship between contours and profiles.
f. Topomap (BBC B : Solent Software) represents any three-dimensional surface and the programme can be used to draw topographic style block-diagrams with adjustable vertical angle, rotation and scaling.
g. Sections, slopes and gradients (BBC B) enables the user to draw and save sections from maps, change the vertical exaggeration, and measure slopes.
h. Contours, maps and cross-sections (BBC: Longman) is in the process of being prouced and will become available in mid-1986.

Clearly the micro-computer should provide the teacher with with invaluable assistance in imparting three-dimensional graphicacy skills to pupils in the future.

4.1.3.7. Games and simulation.

There is no doubt that the abstract exercise that catches the imagination of the pupil will have more effect than a 'dry' abstract exercise to be performed for its own sake. If competition can be introduced, such as performing mapwork skills to 'rescue someone in a mountain region' or to 'assess the effects of damming a valley' (Kemp, 1983) or a 'police hunt' (Proctor, 1983), the excercise is likely to motivate pupils. There are no commercially produced games but they should be simple to construct by introducing map reading elements and perhaps the element of chance promoted by dice.

4.1.3.8. Using photographs and stereo pairs.

The value of using maps in conjunction with photographs and stereo-pairs is clear. Liebenberg (1976), uses this premise to base the construction of his book, The South African Landscape, on having a 1:50 000 map extract facing a pair of photographs ready for stereo viewing of the same area. McGee (1982) showed that children as young as six years-old are able to perceive the overhead view from an aerial photograph, so that stereo-pair viewing is a very valuable additional skill to help pupils visualise the third-dimension on the topographical map.

4.1.3.9. Exercises.

Practical exercises of the type published in the text books and specialised mapwork texts, are very valuable for re-inforcing three dimensional graphicacy skills developed. Where they should be used is to revisit skills learned in one of the ways outlined, and the exercises should not be used to introduce new skills. Practice in drawing profiles and obliques, and skill and perception tests, particularly interpretive skills, should be practiced regularly. Perhaps a major reason for the failure of pupils to perform well in examinations is that they do not have enough practice and that mapwork, once considered learned by the teacher, is then shelved.

4.1.3.10. Overhead projector.

The overhead projector has the useful property of allowing a profile to be placed in position over a map so that the projected image superimposes a sideview onto an overhead view. This is best introduced to senior pupils who have problems in relating cross-sections to the map. A photocopied image of the map that they have in front of them can be projected onto a screen so that they can pinpoint the teacher's directions on their maps.

4.2. OVERVIEW AND IMPLICATIONS : SOME CONCLUDING REMARKS REGARDING THE PROBLEM OF POOR PERFORMANCE IN THREE-DIMENSIONAL MAPWORK.

This research investigation has shown that pupils world-wide, and particularly in South African Secondary Schools appear to perform badly in contour mapwork tests. This problem poses three questions of key importance that need to be addressed. They are, what skills are involved, when should they be introduced and how should they be taught. Their complexity has been exposed with an introductory mapwork calculation, (Introduction) and divided into four main research fields.

A review of available literature (Chapter One) indicates that problems involved in the field of three-dimensional graphicacy can be approached from these four perspectives. The first perspective is to investigate the map itself. A map attempts to convey spatial messages in symbolic convention. Keates (1982), Morrison (1975), (Ratajsky (1977), Robinson (1978), Underwood (1981), and others have focused attention on the map as a communication document that plays the central role in the mapwork system. Balchin and Coleman (1965) coined the term 'graphicacy' to represent the language of maps and spatial communication and stressed its importance as one of the essential underpinnings of education in general. The language has many problems and these have been considered.

The second perspective focuses on the mapworker in the map reading interaction. A range of multi-complex physical processes are involved in the transmission of map language through human eyes to the brain. Ditchburn (1973), Downs and Stea (1977), Keates, (1982), and Neisser (1968), have shown how intricate the operation is. Gazzaniga (1972) has focused attention on left-brain and right-brain differences and Blake (1979) has related this research to geography and geographical skills. It would appear that findings in this field may reveal individual differences which, when treated appropriately, may be part of the remedy for contour reading problems of the future.

A third perspective viewpoint is that of perception of space, which is a field that has long been of interest to psychologists, (Piaget and Inhelder, 1948). More recently Keates(1982), and others have payed attention to recognition of shapes and objects. Particularly pertinent to contour mapwork are Gibson's (1950) 'texture gradient effect', Rubin's (1958) 'figure-ground effect' and Neisser's (1968) work. Thurstone (1944) followed by Satterly (1964) drew the attention of geographers to the importance of gestalt findings and the importance of embedded shapes and 'background noise' to mapwork. Cooper Metzler and Shepard (1984) are conducting research in the field of three-dimensional perception of rotating images that represent three-dimensions on a two-dimensional plane. Applying their findings to the field of contour mapwork will certainly go part of the way to explaining why some pupils can think abstractly in the third dimension while others cannot.

The fourth major perspective from which to view the problem is the stage of conceptual development of the map worker. The definitive works in this field have been done by Piaget and colleagues (1963, 1972) and Bruner (1960, 1967). Although their ideas appear to conflict they are compatible when approached from a practical point of view. The key ideas of interest concern the importance of action on the part of the pupil if concepts are to be acquired and the different stages of development that the child passes through towards maturity. Rhys (1972) investigated the development of logical thinking and applied it to the field of geography. His conclusion is worthy of careful note, that a pupil's readiness to accept concepts is imperative in the development of graphicacy skills.

Certain key studies that helped illuminate the problems in the field of three-dimensional graphicacy were discussed. The Training College Group Committee of the Geographical Association (1941) reported that boys and girls can 'read' contour patterns at a younger age than is commonly supposed and thatthis is a capacity that might exist without any specific teaching. Satterly (1964) offered a different view and he indicated that a test for embedded shapes was the best single predictor of mapwork ability. Boardman and Towner (1979) and later Boardman (1982) devised tests to show that understanding of relief as shown on contour maps develops steadily with age but is still incomplete in many pupils by the time they leave school. Griffin and Lock (1979) focused on the problem of perceptual difficulty and claimed that while conceptual difficulty existed failure to judge relative steepness of slope is more a perceptual error. Phillips, de Lucia and Skelton (1975) considered the potential weakness of the contour symbol as perhaps being the major cause of the problem of poor interpretation attainment. Phillips (1979) investigated methods of improving contour displays but found no improvement in any of them. Underwood (1983) reported that expectancy built from previous experience is the dominant influence on contour interpretation.

The present state of affairs in South Africa was then investigated in Chapter Two. The examination began with a review of teacher orientated literature from 1921 to the present, and this was followed by an inspection of South African Secondary School syllabuses. The shortcomings of text-book treatment and examination treatment of three-dimensional graphicacy was exposed, and the review of the South African situation was concluded with a questionnaire that tested teachers' views.

In Chapter Three an attempt has been made to identify some of the reasons for poor mapwork by duplicating or modifying selected research models. The first two experiments tested how far children of different ages have an understanding of contour mapwork with the aim of clarifying the answer to the question of 'what skills' are involved. Three experiments then tested perceptual and conceptual processes involved in contour mapwork in an attempt to address the question of 'when' contour mapwork should be introduced. The final two experiments explored the realm of three-dimensional thinking by relating cube rotation test performances with mapwork proficiency. None of these tests were intended to be definitive, rather the aim was to attempt to test the ideas of others by applying them to a local situation, and then extending the ideas gained thereby into a pilot study that attempted to correlate two key aspects of three-dimensional graphicacy. Because the experimental treatment was low key and was not intended to prove anything new, the samples chosen to perform the tests were very much convenience samples and cannot be regarded as representative of a wider population. However, the tests did show that the chosen exemplar research studies had parallel results when applied in the local setting and that the conclusions reached were valid in this application.

Chapter Four attempted to address the key questions posed in the introduction. The question of 'what are the appropriate skills?' is met with a structured list of skills. The question of 'when should these skills be introduced?' is met with a scheme of work planned to meet the needs of the pupil at his/her special stage of intellectual development. Finally the question of 'how should these skills be taught?' is met with a Teacher Guide which lists ideas related to the previous two questions. Clearly a contour mapwork course such as outlined in this chapter must be seen in the context of the wider stage of mapwork skill development. Such a full mapwork course should take heed of the theoretical ideas in spatial concept development and at the same time remember the special needs of the teacher who has the responsibility of transmitting the skills to the pupils. The practical approach outlined in this chapter aims to help teachers solve the problem of poor performance in contour mapwork.

The 1939 Memorandum on the Teaching of Geography pointed out that there is opportunity for educational research in making contour-map reading simpler. That opportunity is still wide open in 1986 but, as Board and Taylor, (1977) have warned, it has been fashionable to dismiss maps as being irrelevant or useless in geographical research. It is hoped that academic geographers in the future will shed their indifference and become involved with problems of how best to improve three-dimensional graphicacy at secondary, and inevitably, at tertiary levels.

BIBLIOGRAPHY

ABLER, R, ADAMS, J. and GOULD, P. (1972) Spatial Organization : The Geographer's View of the World London Prentice Hall.

ALMY, M. (1967) A Psychologist Looks at Spatial Concept Formation in The Social Sciences and Geographic Education. 67-81. New York Wiley.

ARNHEIM, R. (1970) Visual Thinking London Faber and Faber.

BADY, R.J. (1978) Comments on Current Uses of Piaget's Concept of Stage. Journal of Research in Science Teaching. 15, 573-574.

BAILEY, P. (1974) Teaching Geography London David Charles.

________. (1979) Teaching and Learning from Landscape and Map Cartographic Journal. 16, 21-23.

________. (1984) The Map in Schools : a Key, a Language and a Set of Skills Cartographic Journal. 21, 62-65.

BALLANTYNE, R. (1980) Spatial Concept Development and the Teaching of Geography in Primary Schools M.A. Thesis University of Natal.

________. (1984) Teachers Need to Visit Psychologists. S.A. Geographer. 12, 77 - 84.

BALCHIN, W.G.V. (1972) Graphicacy. Geography. 57, 185-195.

________. and COLEMAN, A.M. (1973) Graphicacy should be the Fourth Ace in the Pack. 78-85. In Perspectives in Geographical Education Editors Bale, Graves, Walford London Oliver and Boyd.

BARTHOLOMEW, J.C. and KINNIBURGH, I. (1973) The Factor of Awareness Cartographic Journal. 10, 59-63.

BARTLETT, V.L. (1979) Sequence in Topographic Map Interpretation Proceedings of the 10th New Zealand Geographical Conference and 49th ANZAAS Congress of Geographic Sciences. 300 - 304.

BARTON, T.F. (1964) Geography Skills and Techniques in Curriculum Guide for Geographic Education Editor Hill Oklahoma City Harlow Co.

BARTZ, B.S. (1970) Maps in the Classroom Journal of Geography. 18-24.

BEARD, R. (1969) An Outline of Piaget's Developmental Psychology London Routledge and Kegan Paul.

BETAK, J.F. (1975) The Conceptual Locus of a Two-dimensional Language : Some Implications for Human Responses to Two-dimensional Displays. Geographical Analysis. 7, 1-17.

BLAKE, W.E. (1979) Right-left Brain Functions : Geographic Implications Journal of Geography. 78, 246.

BLAKEMORE, C. (1977) Mechanics of the Mind Cambridge University.

BLAUT, J.M. (1974) Mapping at the Age of Three The Journal of of Geography. 73, 5-12.

________. and STEA, D (1971) Studies of Geographic Learning Annals of the Association of American Geographers. 61, 387-393.

BLOOM, B.S. (1956) Taxonomy of Educational Objectives : Handbook I, Cognitive Domain New York McKay

BOARD, C. (1967) Maps as Models in Models in Geography. 672-673. Editors Chorley and Haggett London Methuen.

________. and TAYLOR, R.M. (1977) Perception and Maps : Human Factors in Map Design and Interpretation Transactions of the Institute of British Geographers New Series. 2, 19-36.

BOARDMAN, D. (1976a) Developing a Curriculum Unit Teaching Geography. 2, 20-24.

________. (1976b) Graphicacy in the Curriculum Educational Review Vol. 28 Number 2.

________. (1983) Graphicacy and Geography Teaching London Croom Helm.

_________. and TOWNER, E.	(1980)	Problems of Correlating Air Photographs with Ordnance Survey Maps Teaching Geography 6, 76-79.
BOXHALL, C. and DEVEREUX, E.J.P	(1972)	Contours London George Philip
BRANDES, D.	(1983)	Sources for Relief Representation Techniques The Cartographical Journal. 20, 87-94.
BROOKS, W.D. and PINZKE, K.G.	(1971)	A Computer Programme for Three-Dimensional Presentation of Geographic Data Canadian Cartographer. 8, 110-125.
BROWN, T.W.	(1960)	Report of a Discussion on Mapwork and the Use of Maps in Schools Geography. 45, 305-307.
BRUNER, J.	(1960)	The Process of Education. New York. Vintage.
_________.	(1964)	The Course of Cognitive Growth American Psychologist. 19, 1-15.
_________., and AUSTIN, G.	(1956)	A Study of Thinking New York Goodnow and Wiley.
BURTON, M.StJ.W.	(1974)	Field Sketching with the Sixth Form in Umtali Rhodesia Science News. 8, 16-23.
BUTTERWORTH, G.	(1976)	Perception and Cognition : Where do we Stand in the Mid-seventies? 74-83. In Piaget, Psychology and Education. Ed. Varma and Williams London Hodder and Stoughton.
BUTTIMER, A	(1969)	Social Space and Inter-disciplinary Perspective Geographical Review. 59-63.
CARMICHAEL, L.D.	(1969)	The Relief of Map Making Cartographic Journal. 6, 18-20.
CARSWELL, R.J.B.	(1971)	Children's Abilities in Topographic Map Reading Cartographica Monograph (2), 40-45.
CARUSO, P. and PALM, N.	(1973)	Social Space and Social Place Professional Geographer. 25, 221-225.

CASE, R. (1980) The Underlying Mechanism of Intellectual Development in Cognition, Development and Instruction Editors Kirby and Biggs New York, Academic Press

CASTNER, H.W. and LYWOOD, D.W. (1978) Eye Movement Recording : Some Approaches to the Study of Map Perception Canadian Cartographer. 15, 145-158.

__________. (1979) Viewing Time and Experience as Factors in Map Design Research Canadian Cartographer. 16, 145-157.

__________. and WHEATE, R. (1979) Re-assessing the Role Played by Shaded Relief in Topographic Scale Maps Cartographic Journal 16, 77-85.

CATLING, S.J. (1978a) The Child's Spatial Conception and Geographic Education Journal of Geography. 77, 24-28.

__________. (1978b) Cognitive Mapping Exercises a Primary Geographical Experience Teaching Geography. 3, 120-123.

__________. (1980) Map Use and Objectives for Map Learning. Teaching Geography. 6, 15-18.

__________. and CONNER, C. (1981) The Influence of Learning Theory on the Teaching of Geography in Geographical Work in Primary and Secondary Schools Editor Mills London Geographical Association.

CERNY, J.W. and WILSON, J.E. (1976) The Effect of Orientation on the Recognition of Simple Maps Canadian Cartographer. 13, 132-138.

CHORLEY, R.J. and HAGGETT, P. (1967) Models in Geography London Methuen

CHORLEY, R.J. and HAGGETT, P. (1968) Trend Surface Mapping in Geographical Research in Spatial Analysis : A Reader in Statistical Geography Editors Berry and Marble New Jersey Prentice Hall.

COFFEY, W.J. (1981) Geography : Towards a General Spatial Systems Approach. 147-149. London Methuen.

COHEN, D. (1983) Piaget Critique and Assessment Buckingham. Croom Helm.

COLE, J.P. and BEYNON, N.J. (1969) New Ways in Geography Oxford Blackwell.

COOPER, L.A. and SHEPARD, R.N. (1984) Turning Something Over in the Mind Scientific American. 251, 114-122.

COX, G.B. (1968) Topographic Map Studies in Secondary School Vol. 6 Taminga

CUTTING, J.E. and MILLARD, R.T. (1984) Three Gradients and the Perception of Flat and Curved Surfaces Journal of Experimental Psychology : General. 113, 198-216.

__________. (1984) Reflections on Surfaces: A Cross-Disciplinary Reply to Stevens Journal of Experimental Psychology : General. 113, 221-224.

DALE,P.F. (1971) Children's Reactions to Maps and Aerial Photographs Area. 3, 170-177.

DAVID, E. (1940) Children's Maps : an Experiment Geography. 25, 86-89.

________. (1944) The Teaching of Contours Geography. 29, 57-61.

DAY, R.H. (1966) Perception. 18-23. New York W.M.C. Brown Co.

DENT, B.D. (1972) Visual Organization and Thematic Map Communication Annals of the Association of American Geographers. 62, 79-83.

DEREGOWSKI, J.B. (1966) Investigation into Perception Bulletin No.1 University of Zambia Institute for Social Research. 27-33.

__________. (1968) Difficulties in Pictorial Depth Perception in Africa British Journal of Psychology 59, 195-204.

__________. (1968) On Perception of Depicted Orientation International Journal of Psychology. 3, 195-204.

__________. (1968) Pictorial Recognition in Subjects from a Relatively Pictureless Environment African Social Research. 5, 356-364.

______________. and BYTH, W. (1970) Hudson's Pictures in Pandora's Box *Journal of Cross-cultural Psychology*. 1, 315-323.

______________. (1972) Pictorial Perception and Culture *Scientific American*. 227, 82-89.

______________. and ELLIS,D. (1974) Symmetry and Discrimination Learning *Acta Psychologica*. 38, 87-91.

______________. and SERPELL, R. (1980) The Skill of Pictorial Perception : an Interpretation of Cross-cultural Evidence. *International Journal of Psychology*. 15, 145-180.

DICKINSON, G.C. (1979) *Maps and Air Photographs* (Especially Chapt.12 *Bringing in the Third Dimension*, 209-236). London Edward Arnold

DISLEY, J. (1972) *Orienteering* London Faber

DITCHBURN,R.W. (1973) *Eye Movements and Visual Perception* Oxford Clarendon

DODWELL, P.C. (1968) Children's Understanding of Spatial Concepts in *Logical Thinking in Children* Editors Sigel and Hooper New York Holt Rinehart and Winston

DOWNS, R.M and STEA, D. (1977) *Maps in Minds : Reflections on Cognitive Mapping*. 194-207. New York Harper and Row.

__________. (1981) Maps and Metaphors *Professional Geographer* 33, 287-293.

DRIVER, R. (1978) When is a Stage not a Stage? A Critique of Piaget's Theory of Cognitive Development and its Application to Science Education *Educational Research*. 21, 54-61.

EARLE, J. (1975) Toward better Evaluation in Secondary School Geography *South African Geographer*. 27.

EDWARDS, B. (1979) *Drawing on the Right Side of the Brain* Glasgow Fontana/Collins.

EDWARDS, J.H. (1953) How well are Intermediate Children Oriented in Space? *Journal of Geography*. 52, 133-142.

ELIOT, J. (1970) Children's Spatial Visualization in *Focus on Geography - Key Concepts and Teaching Strategies*. Editor Bacon 40th Yearbook of the National Council for Social Studies.

_______. and HAUPTMAN, A. (1981) Different dimensions of Spatial Ability *Studies in Science Education*. 8, 45-66.

EYRE, S.R. (1973) The Spatial Encumbrance *Area*. 5, 320-324.

FAIRGREAVE, J. (1926) *Geography in School*. 143-169. London University of London Press

FELDMAN, S.S. (1971) Conceptual Processes in *Intellectual Development*. 143-154. Editor Sears New York Wiley and Sons

FLAVELL, J.H. (1963) *The Developmental Psychology of Jean Piaget* New York van Nostrand Reinhold

GAGNE, R.M. (1962) The Acquisition of Knowledge *Psychology Review*. 69, 355-365.

GAGNE, R.M. (1966) *The Conditions of Learning* New York Holt Rinehart

GALBRAITH, I. (1983) *Map Reading and Analysis* Oxford Oxford University Press.

GARNETT, O. (1960) *Fundamentals in School Geography* 245-264 London George Harrap

GATRELL, A.C. (1983) *Distance and Space : A Geographical Perspective* Oxford Clarendon

GARDNER, H. (1979) *The Shattered Mind* New York Alfred A. Knopf

GAZZANIGA, M.S. (1972) One Brain - Two Minds? *American Scientist* 60, 311-317.

GERBER, R and WILSON, P.S. (1979) Spatial Reference Systems and Mapping with Eleven-Year-Old Pupils *Geographical Education* Vol.3 Number 3.

_______. (1981a) Young Children's Understanding of the Elements of Maps *Teaching Geography* Vol. 6 Number 2.

_________. (1981b) Factors Affecting the Competence and Performance in Map Language of Children at the Concrete Level of Map Reasoning Geographical Education Vol. 4 Number 1.

_________. (1984) The Development of Competence and Performance in Cartographic Language by Children at the Concrete Level of Map-Reasoning Cartographica. 21, 98-115.

_________. and WILSON, P.S. (1984) Maps in Classrooms in The Geography Teacher's Guide to the Classroom. 146-157 Editors Fien, Gerber and Wilson Melbourne MacMillan.

GIANNANGELO, D.M. and FRAZEE, B.M. (1977) Map Proficiency of Elementary Educators Journal of Geography February, 63-65.

GIBSON, J.J. (1950) The Perception of Visual Surfaces American Journal of Psychology. 63, 376-384.

_________. (1969) Principles of Perceptual Learning and Development New York Meredith.

GIFFARD, E.O. (1961) Maps and Map Work in the Primary School Geography January, 42-49.

GOPSILL, G.H. (1962) The Teaching of Geography. 47-61. London MacMillan

GRAHAM, E. (1982) Maps, Metaphors and Muddles The Professional Geographer. 34, 251-260.

GRASSIE, N.D. (1982) Contouring by Computer : Some Observations in Computers in Geography Editor Rhind and Adams British Cartographic Society Special Publication Number 2. 93-116.

GRAVES, N.J. (1970) Geography in Secondary Education London Heinemann.

GRAVES, N.J. (1975) Learning Problems in Geography : Conceptualisation and Logical Thinking in Geography in Education London Heinemann.

GRAVES, N.J. Editor (1982) New Unesco Source Book for Geography Teaching Hong Kong Longman/the Unesco Press.

GRIFFIN, T.L.C. and LOCK, B.F. (1979) The Perceptual Problem in Contour Interpretation The Cartographic Journal 16, 61-71.

GUELKE, L. (1976) Cartographic Communication and Geographic Understanding Canadian Cartographer. 13, 107-132.

GUILFORD, J.P. (1959) The Three Faces of Intellect American Psychologist. 14, 459-463.

GULLIVER, F.P. (1908) Orientation of Maps Journal of Geography 7, 55-59.

HALL, D. (1978) Geography and the Geography Teacher London Unwin

HALL, R. (1982) Key Concepts : A Reappraisal Geographical Education. 4, 25-34.

HARRISON, D.A. (1978) Cognitive Maps of a Canadian Five-year old Teaching Geography. November, 65-67.

HART, R.A. and MOORE, G.T. (1973) The Development of Spatial Cognition : A Review. 247-288. In Image and Environment. Editors Downs and Stea Chicago Aldine

HARVEY, D. (1969) Explanation in Geography London Arnold.

HEAMON, A.J. (1973) The Maturation of Spatial Ability in Geography Educational Research. 16, 63-66.

HELM, H. (1978) Misconceptions about Physical Concepts Amongst S.A. Pupils Studying Physical Science South African Journal of Science. 72, 63-66.

HOCHBERG, J.E. (1964) Perception. 82-89. New Jersey Prentice Hall

HOOPER, F.H. (1969) Piagetian Research and Education. Logical Thinking in Children : Research Based on Piaget's Theory New York Holt International

HSU, M-L. and ROBINSON, A.H. (1970) The Fidelity of Isopleth Maps. An Experimental Study Minneapolis University of Minnesota.

HUDSON, W. (1960) Pictorial Depth Perception in Sub-Cultural Groups in Africa Journal of Social Psychology. 52, 183-208.

________. (1962) Pictorial Depth and Educational Adaptation in Africa. Psychologia Africana. 9, 226-239.

________. and HALL, F. (1973) A Study of Pictorial Perception South African Journal of Science. 58, 188-190.

HURRY, L.B. (1978) A Handbook for Geography Teaching in South Africa Goodwood Via Afrika.

IMPERATORE, W. (1970) On the Nature of Concepts Journal of Geography. 173-178.

INCORPORATED ASSOCIATION OF ASSISTANT MASTERS IN SECONDARY SCHOOLS (1939) Memorandum on the Teaching of Geography 174-179. London George Philip and Son.

JENKS, G.F., STEINKE, B., BUCHERT, B. and ARMSTRONG, L. (1971) Illustrating the Concepts of the Contour Symbol, Interval and Spacing via 3-D Maps. Journal of Geography. 70, 280-288.

JONES, F.G. (1982) The Relationship Between Map Perception and Conceptualisation : A Review of the Literature New Zealand Journal of Geography April. 12-15.

KEATES, J.S. (1982) Understanding Maps London Longman.

KEMP, R. (1983) Mapwork One, and Mapwork Two London Edward Arnold.

KENT, A. (1983) Geography Teaching and the Micro London Longman.

KING, C. (1982) 3D into 2D - Teaching Contours Using an Overhead Projector Teaching Geography April. 159.

________. (1985) Paper Models of Landforms as Exercises in Three-Dimensional Thinking Teaching Geography April. 107-109.

KING, L.C. (1969) Analysis of Spatial Form and its Relation to Geographic Theory Annals of Association of American Geographers. 59, 573-595.

KIRBY, J.R. and BIGGS, J.B. (1980) Cognition, Development and Instruction 23-37. New York Academic Press.

KOEMAN, C. (1971) The Principle of Communication in Cartography International Yearbook of Cartography. 11, 169-176.

KOFFKA, K. (1924) The Growth of the Mind Harcourt Brace and World

KOHN, C. (1966) A Balanced Approach to Developing a Geography Curriculum Journal of Geography. 65, 356-358

KOLACNY, A (1969) Cartographic Information - A Fundamental Term in Modern Cartography. The Cartographic Journal. 6, 39-46.

KOLODIY, G.O. (1977) Cognitive Development and Science Teaching Journal of Research in Science Teaching 14, 21-26.

LABINOWICZ, E. (1980) The Piaget Primer : Thinking, Learning, Teaching Canada Addison Wesley.

LANGER, J. (1969) Theories of Development New York Holt, Rinehart and Winston.

LAPPAN, G., PHILLIPS, E.A. and WINTER, M.J. (1984) Spatial Visualisation Mathematics Teacher November. 618-625.

LEDGER, R.H. (1978) The New Geography in South African High School Teaching M.A. Thesis submitted to University of Cape Town.

LEIBOVIC, K.N. (1972) Nervous System Theory New York Academic Press.

LEVY, J. (1974) Psychobiological Implications of Bilateral Asymmetry in Hemisphere Functions in the Human Brain Editors Dimond and Beaumont New York John Wiley and Sons.

LINKE, R.D. (1975) Replicative Skills in Hierarchical Learning of Geographical Interpretation Skills British Journal of Educational Psychology 45, 39-46.

LONG, M. and ROBERSON, B.S. (1966) Teaching Geography. 52-67. London Heinemann.

LOWENTHAL, D. (1961) Geography Experience and Imagination : Towards a Geographical Epistemology Annals of the Association of American Geographers 51, 241-260.

LUCAS, J.R. (1973) A Treatise on Time and Space London Methuen.

MacFARLANE-SMITH, I. (1964) Spatial Ability : Its Educational and Social Significance London London University Press.

McGEE. C.F. (1982) Children's Perceptions of Symbols on Maps and Aerial Photographs Geographical Education 4, 51-59.

McGUIGAN, F.J. (1957) An Investigation of Several Methods of Teaching Contour Interpretation Journal of Applied Psychology. 41, 53-57.

MANLEY, D. (1976) Maps and Map Games. 35-46. London Piccolo

MARSDEN, W.E. (1976) Evaluating the Geography Curriculum. 137-142. Edinburgh. Oliver and Boyd.

MATTHEWS, M.H. (1984) Cognitive Mapping Abilities of Young Boys and Girls Geography. 327-336.

MEYER, J.T. (1977) Geography Space and Diffusion : a Thematic Analysis of a Conventional Wisdom M. Sc. Thesis Pennsylvania State University.

MICHIE, W.D. (1974) The use of Concepts in Geography Teaching. Proceedings of the Geographical Association of Rhodesia Number 7 December. 52-54.

MIDGELY, H. and WALKER, R. (1985) An Introduction to Microcomputers in Geography Teaching London Hutchinson

MILLER, A.A. (1953) Surface Morphology : The Relief Map in Skin of the Earth London University Paperbacks Methuen.

MILLS, D. (1981) Graphicacy in Geographical Work in Primary and Middle Schools The Geographical Association London.

MONKHOUSE, F.J. and WILKINSON, H.R. (1963) Maps and Diagrams London Methuen

MONMONIER, M.S. (1982) Computer Assisted Cartography Principles and Prospects New Jersey Prentice Hall.

MORRISON, J.L. (1974) A Theoretical Framework for Cartographic Generalisation with Emphasis on the Process of Symbolisation International Yearbook of Cartography. 14, 115-127.

__________. (1976) The Science of Cartography and its Essential its Processes International Yearbook of Cartography. 16, 84-97.

__________. (1978) Towards a Functional Definition of the Science of Cartography with Emphasis on Map Reading The American Cartographer. 5, 97-110. Number 2.

MUNOWENYU, E. (1985) Another bright Idea - from 2D to 3D. Teaching Contours using Polystyrene Teaching Geography January. 90-91

NAISH, M. (1977) The Development of Children's Thinking in School Geography Teaching Geography. 81-84.

NEISSER, U. (1968) The Process of Vision Scientific American. 219, 204-214.

OBERLANDER, T.M. (1968) A Critical Appraisal of the Inclined Contour Technique of Surface Representation Annals of the Association of American Geographers 58, 802-813.

PETCHENIK, B.B. (1977) Cognition in Cartography Cartographica The Nature of Cartographic Communication. Monograph Number 19. 117-127.

PIAGET, J. (1955) The Child's Construction of Reality London Routledge and Kegan Paul.

__________. and INHELDER, B. (1956) The Child's Conception of Space London Routledge and Kegan Paul.

________. INHELDER, B. and SZEMINSKA, A.	(1960)	The Child's Conception of Geometry London Routledge and Kegan Paul.
PHILLIPS, R.J., DE LUCIA, A. and SKELTON, N.	(1975)	Some Objective Tests of the Legibility of Relief Maps Cartographic Journal. 12, 39-46.
PHILLIPS, R.J.	(1979)	An Experiment with Contour Lines The Cartographc Journal. 16, 72-77.
PIRIE, G.	(1968)	The Challenge of Orienteering London Pelham.
POTASH, L.M., FARRELL, J.P. and JEFFREY, T.A.	(1978)	A Technique for Assessing Relief Map Legibility Cartographic Journal. 15, 28-35.
POWER, R.P., HAUSFELD, S and GORTA, P.	(1981)	Workshops in Perception London Routledge and Kegan Paul.
PROCTOR, D.	(1983)	Mapwork London Edward Arnold.
RAISZ, E.	(1962)	Principles of Cartography. 68-74. New York McGraw-Hill.
RATJASKY, L.	(1977)	The Research Structure of Theoretical Cartography Cartographica. 19, 46-58.
RENNER, G.T.	(1941)	Educational Revision of Wall Maps Journal of Geography. 40, 13-19.
REPORT BY THE TRAINING COLLEGE GROUP COMMITTEE	(1941)	An Investigation into Children's Ability to Interpret Contour Lines Geography. 26, 131-140.
RHYS, W.	(1972)	The Development of Logical Thinking in New Movements in the Study and Teaching of Geography Editor Graves London Temple Smith
RICHARDS, P.	(1974)	Kant's Geography and Mental Maps Transactions of the Institute of British Geographers. 16, 6-13.
RIFFEL, P.A.	(1969)	A New Approach to Teaching Map Reading The Journal of Geography December. 554-556.

ROBERTS, J.A. (1962) The Topographic Map in a World of Computers Professional Geographer. 14, 12-13.

ROBINSON, A.H. and SALE, R.D. (1969) Elements of Cartography New York John Wiley and Sons.

__________. and PETCHENIK, B.B. (1976) The Nature of Maps. Essays toward Understanding Maps and Mapping. Chicago The University of Chicago.

__________. and PETCHENIK, B.B. (1977) The Map as a Communication System Cartographica The Nature of Cartographic Communication Monograph No.19, 92-109.

__________. (1978) The Uniqueness of the Map The American Cartographer. 5, 5-7.

ROCK, I. (1974) The Perception of Disorientated Figures. Scientific American. 230, 74-85.

______. (1975) The Perception of the Third Dimension in An Introduction to Perception New York MacMillan.

ROWELL, J. and HOFFMAN, P.J. (1975) Group Tests for Distinguishing Formal from Concrete Thinkers Journal of Research in Science Teachingl. 12, 157-164.

RUBIN, E. (1958) Figure and Ground in Readings in Perception 194-203. Editors Beardslee and Wertheimer Princeton. Van Nostrand.

RUSHDOONY, H.A. (1968) A Child's Ability to Read Maps : Summary of the Research The Journal of Geography 213-219.

__________. (1971) The Geographer, the Teacher and a Child's Perception of Maps and Mapping Journal of Geography. 70, 429-433.

ST-ARNAUD, R. (1971) The Role of the User in the Map Communication Process : The Topographic Map and the Map User Cartographica Monograph No.2, 18-23.

SALICHTCHEV, K.A . (1978) Cartographic Communication : Its Place in the Theory of Science Canadian Cartographer 15, 93-99.

SANDFORD, H.A. (1972) Perceptual Problems in New Movements in the Study and Teaching of Geography. 83-92. Editor Graves London Cheshire

______. (1978) Taking a Fresh Look at Atlases. 62-65. Teaching Geography November.

______. (1979) Things Maps Don't Tell Us Geography. 64, 297-302

SATTERLY, D. (1964) Skills and Concepts Involved in Map Drawing and Map Interpretation. New Era. 45, 260-263.

SAVAGE, T.V. and (1969) Teaching Symbolic Map Skills with Primary Grade Children Journal of Geography. 68, 491-497.

SAYRE, S. and BALL, D.W. (1975) Piagetian Cognitive Development and Achievement in Science. Journal of Research in Science Teaching. 12, 165-174.

SEDDON, G.M., TARIQ, R.H., and DOS SANTOS VEIGA, J. (1984) The Transferability of Two Pictorial Tasks Between different Spatial Dimensions British Journal of Educational Psychology 54, 276-283.

______., ENIAIYEJU, P.A. JUSOH, I. (1984) The Vizualization of Rotation in Diagrams of 3-Dimensional Structures American Educational Research Journal. 21, 25-38.

SHEPARD, R.N. and METZLER, J. (1971) Mental Rotation of Three-Dimensional Objects Science. 171, 701-703.

SHEPHERD, I.D.H., COOPER, Z.A. and WALKER, D.R.F. (1980) Computer Assisted Learning in Geography London CET/Geographical Association

SNYDER, S., FELDMAN, D., and LA ROSSA. (1975) Manual for Piaget Base-map Drawing Exercise Medford Massachusetts.

STEINKE, T. and LLOYD, R. (1983) Images of Maps : A Rotation Experiment Professional Geographer. 35, 455-461.

STOLTMAN, J.P. and GOOLSBY, T.M. (1973) Developing Map Skills Through Reading Instruction The Journal of Geography. 32-36.

STORM, M.J. (1966) Making Sense of Maps The Teacher 30 September.

SUTCLIFFE, G.P. (1983) Making Scale Relief Models in Schools Teaching Geography January. 110-111.

TALLEY, L.H. (1973) The Use of Three-Dimensional Visualization as a Moderator in the Higher Cognitive Learning Chemistry Journal of Research in Science Teaching. 10, 263-269.

TANAKA, K. (1950) The Relief Contour Method of Representing Topography on Maps Geographical Review. 40, 444-456.

THORNDYKE, P.W. (1980) Individual Differences in Procedures for Knowledge Acquisition from Maps Cognitive Psychology. 12, 137-175.

THURSTONE, L.L. (1944) A Factorial Study of Perception Chicago The University of Chicago Press.

TOWLER, J.O. and NELSON, L.D. (1968) The Elementary School Child's Concept of Scale The Journal of Geography. 24-28.

UNDERWOOD, J.D.M. (1981) Skilled Map Interpretation and Visual Spatial Ability Journal of Geography. 55-58.

________________. (1983) Influencing the Perception of Contour Lines The Cartographic Journal. 18, 116-119.

UNWIN, D. (1981) Introductory Spatial Analysis London Methuen.

VAN DER SPUY, J.W. (1966) Some Hints on Teaching the Representation of Relief Journal for Geography. 2, 49-54.

VERNON, M.D. (1970) Perception through Experience. 27-47. London Methuen

VINACKE, W.E. (1952) The Psychology of Thinking London McGraw-Hill.

WALKER, M.J. (1976) Changing the Curriculum Teaching Geography April. 163-165.

WALLIS, B.C. (1921) The Teaching of Geography. 142-150. London Cambridge University Press.

WARREN, J.W. (1976) Standards of Criticism Physical Education 11. 25-27.

WELCH, R.V. (1978) Conflict Apparent and Real : A Review of Concepts of Space in Geography New Zealand Geographer. 34, 24-30.

WELCH, S.L. (1981) A Critical Examination of Concept Analysis and its Application to Concepts of Space in Geography M.A. Thesis Rhodes University Grahamstown

WHITE, R.T. (1973) Research into Learning Hierarchies Review Educational Research. 43, 361-375.

WOOD, M. (1968) Visual Perception and Map Design Cartographic Journal. 5, 54-64.

WORTH, C. (1978) Determining a Vertical Scale for Graphical Representations of Three-Dimensional Surfaces The Cartographic Journal. 15, 86-91

YOELI, P. (1983) Shadowed Contours with Computer and Plotter The American Cartographer. 10, 101-110.

YOUNG, J.Z. (1962) Why do we have two brains? in Interhemispheric Relations and Cerebral Dominance Editor Mountcastle Baltimore The John Hopkins Press.

YOUNG, J.Z. (1978) Programs of the Brain Oxford Oxford University Press.

ZAKRZEWSKA-BOROWIECKI, B. (1974) Landform analysis from Topographic Maps Journal of Geography. 73, 7-20.

ZA'ROUR, G.I. (1975) Science Misconceptions among Certain Groups of Students in Lebanon. Journal of Research in Science Teaching. 12, 385-391.

APPENDIX A

GLOSSARY OF TERMS

ACCOMMODATION
Adjustment of the mapworker's understanding of past experiences in the light of new perceptions. Previous learning is accommodated so as to assimilate new.

ASSIMILATION
The taking in of new experiences and fitting these into existing conceptual structures.

CONCEPT
A classificatory device enabling the structuring of reality in a simplified manner by concentrating on the essential attributes of certain experiences. (Graves's definition.)

'in the ordering of reality, the intellect perceives through and manipulates words which it has created and applied to things. The content of thought is thus essentially verbal...' (Rice, 1967)

CONCEPT FORMATION
Is concerned with the process of acquiring characteristics of the concept which enable information to be ordered or categorised.

CONCRETE OPERATIONS
Mental operations which characterise the thinking of children aged about 7 to 12 years. Thinking is linked to concrete reality more than to abstract ideas.

CONTOUR,
'a line drawn on a map through all points which are at the same height above, or depth below, sea level'. He stresses that contours are lines drawn on maps and do not appear on the ground. Boardman's (1983) recommended definition of a contour.

EMBEDDED SHAPES
A complex arrangement of lines, points and patterns where the patterns overlap and interweave on a topographical map.

FORMAL OPERATIONS
The final stage in the development of thinking, according to Piaget. Concrete operations have been internalised, so that they can now be carried out mentally and thinking in abstract becomes possible.

GRAPHICACY
A term first used in an article by Balchin and Coleman (1965). They argued then and since that there are four main orders of communication - literacy, numeracy, articulacy and graphicacy. Balchin defined graphicacy as the art of communicating spatial information that cannot be conveyed by verbal or numerical means.

LEARNING
Is a change in behaviour due to practice.

MAP
A storage medium that has scale, projection and a set of abstract signs.

MAPPING
The transmission and receipt, in any medium, of information about distance, direction, and landscape fetaure or site, information of the sort contained in a 'cognitive map'. (Blaut and Stea's definition).

NEUROPHYSIOLOGY
The term used by Neisser (1968, p.207) to describe the physical processes in vision from the retina to the brain.

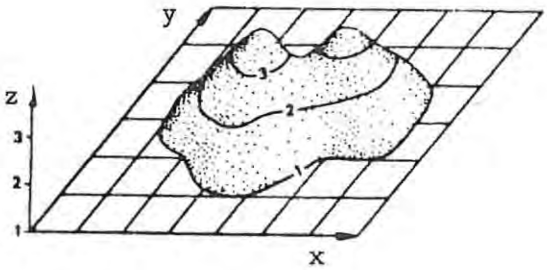
ORIENTEERING
The sport of making one's way on foot quickly across difficult country with the help of a compass and a map.

PERCEPTION
The 'contact' with environment, established by the senses of smell, touch, hearing and sight. Some kind of recognition is singled out from a mass of undifferentiated stimuli.

SCALAR FIELD
The third dimension on a large-scale topographical map involves a surface with the spatial dimension ofL whereby the map displays two horizontal dimensions or axes and symbolises the third dimensional volume of the surface. In three dimensional surface mapping the mathematical concept of a scalar field is a useful means by which to analyse the spatial co-ordinates. Scalar fields can be represented mathematically by the general equation :

$$z = f(x,y)$$

where z = scalar magnitude; x,y = spatial co-ordinates; and f denotes the function (Unwin, 1981) shown diagramatically (p.131).



Scalar fields can be mapped in a number of ways from simple point representations through to complex isolines.

The simplest representation is to plot the z scale as a number of points. These points could be significant ones such as the top of a peak or in a valley or they could be randomly placed.

SPACE (TYPES OF) :

TOPOLOGICAL SPACE.
Topology refers to the study of spatial equivalence and the most important property in graphicacy is proximity, which is the most elementary theoretical reconstruction of space. Because children's early understanding of their environment is entirely egocentric they become aware of their spatial surroundings solely on a perceptual level. Space is limited and a highly localised practical space explored by visual and tactile senses. Children then begin to move from purely perceptual understanding of their environment to initial spatial conception. This means a mental exercise of recalling their spatial perceptions as images when they are no longer there to observe. As soon as a child can draw a simple connection between parts of a whole he has developed a topological understanding. The drawing need not have orientation, or direction or distance.

PROJECTIVE SPACE
The term projective means the representation of three-dimensional

objects in two dimensions either in plan or elevation form. Projective concepts develop when a child can appreciate how objects appear when viewed from different positions, and can locate them relative to each other without the aid of measurement (Piaget : 1955). A child that has attained the stage of understanding projective space concepts introduces some direction and orientation into his drawing.

EUCLIDEAN SPACE

The term "Euclidean" refers to the spatial geometry of the mind where the world is represented in a comprehensive system of coordinate axes of reference. Space is structured in terms of horizontal and vertical lines and it is abstractly co-ordinated. A Euclidean representation not only has direction and orientation but it also has distance and a roughly accurate scale.

SYLLABUS

A document that is essentially a summary of the content of a course of study.

APPENDIX B

LIST OF SCHOOL TEXT BOOKS IN SOUTH AFRICA REFERRED TO IN CHAPTER 2.4.

BARNARD, W.S., DU TOIT, A.B., LE ROUX, J.S., ANDREW, COETZEE and RETIEF	no date given	*Junior Geography for Std 6* Cape Town Nasou
BARNARD, W.S.and NEL, A.	1982	*Our New World 8* Cape Town Maskew Miller
BARNARD, W.S. and NEL, A.	1981	*Our New World 10* Cape Town Maskew Miller
BATEMAN, R. and MARTIN, F.,		*Steps in Geography* Book 1 London Hutchinson
COLE, J.P. and BEYNON, N.J.	1980	*New Ways in Geography* Book 2 London Basil Blackwell
CRAIG, J.K., SLABBERT, J.A., BOTHA, D.H. and HUGO, P.J.	no date	*Junior Secondary Geography for Standard 6* Cape Town Nasou
CRAIG, J.K., SLABBERT, J.A., BOTHA, D.H. and HUGO, P.J.	no date	*Junior Secondary Geography for Standard 7* Cape Town Nasou
EARLE, J.	1985	*New Window on the World Standard 6* Cape Town Juta
EARLE, J.	1985	*New Window on the World Standard 7* Cape Town Juta
EVANS, H.	1978	*The Young Geographer* Book 4 London Wheaton
GALBRAITH, I.	1983	*Map Reading and Analysis* Oxford Oxford University.
LIEBENBERG, E.C., ROOTMAN, P.J, and VAN HUYSSTEEN, M.K.R.	1980	*The South African Landscape. Exercise Manual for Map and Air Photo Interpretation.* Durban Butterworth
NEL,D.E., LE ROUX, J.S., VAN DER WALT and COETZEE, H.P.C.	no date	*Geography 8* Cape Town Juta

NEL, D.E., BEAVON, K.S.O., . LE ROUX, J. and van der WALT, J	no date	Geography 10 Cape Town Juta
NICHOLSON, J.M. and MORTON, J.G.	1977	Working with Maps Pietermarizburg Shuter and Shooter
PODESTA, B., CONACHER, R., NICOLSON, P. and BOSHOFF, L.	1977	Active Geography Std 7 Pretoria De Jager-Haum
PODESTA, B., CONACHER, R. and VENTER, H.	1978	Active Geography Std 8 Pretoria De Jager-Haum
ROBINSON, A. and WALLWORK, K.	1970	Map Studies with related Field Excursions London Longman
SHAH, C.G, SHAH, D.B. and NAIDOO, P.G.	1982	Map and Aerial Photograph Reading and Interpretation for Secondary Schools Goodwood Nasou
SWANEVELDER, C.J., DU TOIT, and BARNARD, P.J.	no date	Senior Geography for Standard 8 Cape Town Nasou
SWANEVELDER, C.J., KOTZE, J.C., VAN HUYSSTEEN, M. and HANEKOM, F.	1981	Senior Geography for Standard 10 Cape Town
VAN DER SPUY, J., SWANEPOEL, G., NIEMAN, W. and VAN DER MERWE, I.	no date	Our Junior Geography Standard 7 Cape Town Maskew Miller

APPENDIX C

A classification of examination questions used in final school examinations in South Africa

CATEGORY I - KNOWLEDGE AND DEFINITIONS

1. Definition of contour interval
2. Definition of vertical exaggeration
3. Definition of gradient
4. Defintion of elevation

CATEGORY II - PERCEPTUAL INTERPRETATION

5. Identify relief features from the contour patterns
6. Slope description from contour patterns
7. River flow direction from contour patterns
8. Describe a landscape view from contours

CATEGORY III - MAPWORK DRAWING SKILLS

9. Draw (or complete) a profile
10. Identify feature on the profile
11. Intervisibility
12. Measure overland distance
13. Draw contour sketches from verbal descriptions

CATEGORY IV - INTERPRETATION AND ANALYSIS

14. The influence of relief on communications
15. The influence of relief on man-made features
16. A regional description and subdivision

Analysis of examination questions by nine examining boards.

1. DATE - end of year examination unless stated otherwise
2. QUESTIONS - classification as set above
3. MARKS - the marks set in the examination for that question
4. CATEGORY (CAT.) - the classification set out above
5. CLASS - the question types numbered as set out above.
6. TOTAL - the total marks for contour mapwork in that examination and the percentage of the total possible marks in that examination

CAPE SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1985	Complete a profile	9	3	9	
	Identify feature on the profile	2	3	10	
					11 (14%)
1984	Estimate highest point on the map	4	1	4	
	Calculate the gradient of a thalweg	8	1	3	
					12 (15%)
1983	Contour interval	3	1	1	
					3 (4%)
1982	Identify features on a profile	6	3	10	
	Calculate gradient	9	1	3	
	Relief's influence on transport lines	10	4	15	
					25 (31%)
1982 March	Slope description	3	2	6	
	Identify relief feature	3	2	5	
	Contour interval	2	1	1	
					8 (10%)
1981	Identify features on a profile	3	3	10	
	Complete a profile	9	3	9	
	Relief's influence on transport lines	10	4	15	
					22 (28%)
1980	Calculate gradient	3	1	3	
					3 (4%)
1979	Describe a landscape view	12	2	8	
	Complete a profile	12	3	9	
	Calculate a gradient	12	1	3	
					36 (45%)
1978	Highest altitude estimate	2	1	4	
	Calculate gradient	3	1	3	
					5 (6%)
1977	Describe a landscape view	4	2	8	
	Slope description	2	2	6	
	Highest altitude estimate	8	1	4	
	Calculate gradient	5	1	3	
					19 (24%)

CAPE SENIOR CERTIFICATE (STANDARD GRADE)		marks	cat.	class	total
1984	Highest altitude estimate	4	1	4	
	Identify relief feature	2	2	5	
	Regional description classification	4	4	17	
	Relief's influence on (farm size,etc	2	4	16	
	Calculate gradient	4	1	3	
	Identify features on a profile	2	3	10	
					18 (30%)
1983	Nil				0 (0%)
1982	Identify relief feature	3	2	5	
	Identify features on a profile	9	3	10	
	Calculate gradient	6	1	3	
	Relief's influence on transport lines	9	4	15	
					27 (45%)
1982 March	Slope description	3	2	6	
	Identify relief feature	3	2	5	
					6 (10%)
1981	Complete a profile	3	3	9	
	Regional description classification	2	4	17	
	Identify landforms on a profile	12	3	10	
	Relief's influence on transport lines	8	4	15	
					25 (42%)
1980	Nil				0 (0%)
1979	Highest altitude estimate	4	1	4	
	Describe a landscape view	8	2	8	
	Complete a profile	8	3	9	
					20 (33%)
1976	Contour interval	2	1	1	
	Identify relief feature	2	2	5	
	Contour sketches from descriptions	6	3	14	
	Draw a cross section	8	3	9	
	River flow direction	4	2	7	
	Relief's influence on urban expansion	4	4	15	
					26 (43%)

JOINT MATRICULATION BOARD (HIGHER GRADE)		marks	cat.	class	total
1985	Relief's influence on town site	10	4	16	
	Draw a sketch profile and features	30	3	9	40 (50%)
1985 March	Intervisibility	6	3	11	
	Gradient calculation	12	1	3	18 (23%)
1984	Identify relief feature	4	2	5	
	Relief's influence on dam site	6	4	16	
	A regional classification	14	4	17	24 (30%)
1983	Describe a landscape view	2	2	8	2 (3%)
1983 March	Identify features on a profile	10	3	10	
	A regional classification	12	4	17	22 (28%)
1982	Identify features on a profile	18	3	10	
	Relief's influence on site of hotel	4	4	16	
	Identify relief features (ridges)	2	2	5	24 (30%)
1982 March	Gradient calculation	6	1	3	
	Complete a profile	12	3	9	
	Vertical scale of a profile	2	1	2	
	Vertical exaggeration calculation	4	1	2	
	Intervisibility	4	3	11	28 (35%)
1981	Slope direction	4	2	7	
	Identify relief features	8	2	5	12 (15%)
1979	Describe a landscape view	16	2	8	
	Complete a profile/intervisibility	8	3	9/11	24 (30%)
1978	Identify features on a profile	14	3	10	
	Vertical exaggeration calculation	4	1	2	
	Describe a landscape view	10	2	8	
	Identify features on a profile	4	3	10	32 (40%)

JOINT MATRICULATION BOARD (STANDARD GRADE)		marks	cat.	class	total
1985	Relief's effect on town site	10	4	16	
	Identify features on a profile	20	3	10	
					30 (50%)
1984	Identify relief features	6	2	5	
	Relief's influence on dam site	6	4	16	
	Relief's influence on town site	10	4	16	
					22 (37%)
1984	Relief's influence on dam site	6	4	16	
March	Relief's influence on transport lines	6	4	17	
					12 (20%)
1983	Vertical interval	2	1	1	
	Describe a landscape view	2	2	8	
					4 (7%)
1982	Relief's influence on a hotel site	4	4	16	
					4 (7%)
1981 (March)	Nil				0 (0%)
1980	Relief's influence on town site	4	4	16	
	Altitude estimation	4	1	4	
					8 (13%)

DEPARTMENT OF INTERNAL AFFAIRS SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1984	Identify relief feature	2	2	5	
	Estimate altitude	2	1	4	
	Complete profile	6	3	9	
	Calculate vertical exaggeration	4	1	2	
					14 (18%)
1982 March	recognise profiles	4	3	10	4 (5%)
1981	Regional description classification	2	4	17	
	Estimate altitude	2	1	4	
	Relief's influence on transport lines	2	4	15	
	Relief's influence on agriculture	6	4	16	
	Describe a landscape view	8	2	8	
	Calculate gradient	5	1	3	
	Slope description	1	2	6	
					26 (33%)
	(STANDARD GRADE)				
1984	Estimate altitude	2	1	4	
	Complete profile	6	3	9	
					8 (13%)
1982	Complete profile	5	3	9	
	Identify features on a profile	2	3	10	
					7 (12%)
1981	Estimate highest altitude	2	1	4	
	Regional description classification	2	4	17	
	Relief's influence on transport	4	4	15	
	Identify relief features	6	2	5	
	Complete a profile	7	3	9	
	Identify features on a profile	3	3	10	
					24 (40%)

DEPARTMENT OF INTERNAL AFFAIRS (INDIAN) SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1984	Nil				0 (0%)
1983	Flow direction of a river	5	2	7	5 (6%)
1981	Draw a profile	5	2	9	8 (10%)
	Relief's influence on transport lines	3	4	15	
	(STANDARD GRADE)				
1984	Flow direction of a river	4	2	7	4 (6%)
1983	Height difference between two beacons	3	1	4	9 (15%)
	Flow direction of a river	6	2	7	
1981	Relief's influence on railway line	3	4	15	3 (5%)

O.F.S. SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1984	Calculate gradient	8	1	3	8 (10%)
1982	Calculate gradient	8	1	3	8 (10%)
	(STANDARD GRADE)				
1984	Describe a landscape view	4	2	8	4 (7%)
1982	River flow direction	4	2	7	6 (10%)
	Compare two relief regions	2	2	8	

NATAL SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1984	Identify relief feature	1	2	5	
	Original river course through a dam	3	3	14	
					4 (5%)
1983	Identify relief feature	2	2	5	
	Gradient calculation	2	1	3	
	Identify features on a profile	2	3	10	
	Draw a profile	3	3	9	
	Describe a landscape view	6	2	8	
					15 (19%)
1982	Elevation estimate	2	1	4	
	Draw a profile	3	3	9	
	Identify relief feature	1	2	5	
	Relief's influence on communications	3	4	15	
	River flow direction	3	2	7	
					12 (15%)
	(STANDARD GRADE)				
1984	Relief's influence on railway line	4	4	15	
					4 (7%)
1983	Elevation estimate	2	1	4	
	Relief's influence on railway line	4	4	15	
					6 (10%)

NATIONAL SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1985 3 Feb.	Calculate slope gradient	10	1	10	10 (13%)
1984 (N1)	Relief's influence on railway line Identify relief features Elevation estimate	4 13 2	4 2 1	15 5 4	19 (24%)
1984 (N5)	River flow direction Identify relief features Relief's influence on road flow line Identify features on a profile	2 6 2 4	2 2 4 3	7 5 15 10	14 (18%)
1984 June	Gradient calculation River flow direction Identify relief feature Slope description Intervisibility	6 2 6 2 4	1 2 2 2 3	3 7 5 6 11	20 (25%)
1984 Feb.	Describe a landscape view	10	2	8	10 (13%)
1982 March	Identify relief feature Describe a landscape view	2 10	2 2	5 8	12 (15%)
1979	Elevation estimates Contour interval Identify relief feature Relief's influence on transport	12 2 2 6	1 1 2 4	4 1 5 15	22 (28%)

NATIONAL SENIOR CERTIFICATE STANDARD GRADE		marks	cat.	class	total
1985 Feb	River flow direction	6	2	7	6 (10%)
1984 (X)	River flow direction	2	2	7	
	Identify relief feature	6	2	5	8 (13%)
1984 (Y)	Identify relief features	11	2	5	
	Elevation estimate	2	1	4	13 (22%)
1984	Gradient calculation	6	1	3	
June	River flow direction	2	2	7	
	Identify relief feature	8	2	5	16 (27%)
1984	River flow direction	6	2	7	
Feb.	Relief's influence on town site	6	4	16	12 (20%)
1982	Elevation estimate	4	1	4	
March	Relief's influence on road	4	4	15	
	Contour interval	2	1	1	
	Identify relief feature	2	2	5	12 (20%)
1979	Elevation estimate	6	1	4	
	Contour elevation	2	1	1	
	Identify relief feature	4	2	5	12 (20%)

TRANSKEI SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1983	Contour interval	2	1	1	
	Gradient calculation	5	1	3	7 (9%)
	(STANDARD GRADE)				
1983	Relief's influence on dam site	4	4	16	4 (7%)

TRANSVAAL EDUCATION DEPARTMENT SENIOR CERTIFICATE (HIGHER GRADE)		marks	cat.	class	total
1984	Identify features on a profile	6	2	5	
	Slope descriptions	6	2	6	
	Vertical exaggeration calculation	4	1	2	
					16 (20%)
1983	Relief's influence on railway line	4	4	15	
	Relief's influence on a dam site	6	4	16	
	Complete drawing a profile	6	3	9	
	Identify features on a profile	6	3	10	
					22 (28%)
1982	Gradient calculation	8	1	3	
	Slope description	2	2	6	
					10 (13%)
1981	Identify features on a profile	12	3	10	
	Gradient calculation	8	1	3	
	River flow direction	4	2	7	
	Describe a landscape view	12	2	8	
	Measure overland distance	6	3	13	
					42 (53%)

(STANDARD GRADE)

1984	nil				0 (0%)
1982	Gradient calculation	4	1	3	
					4 (7%)
1981	Complete a profile	10	3	9	
	Identify features on a profile	6	3	10	
	Intervisibility	2	3	11	
	Identify relief features	10	2	5	
					28 (47%)
1979	Identify features on a profile	8	3	10	
	Identify relief features	2	2	5	
	Contour interval	2	1	1	
	Elevation estimation	2	1	4	
					14 (24%)

APPENDIX D

QUESTIONNAIRE OF TEACHERS' ATTITUDES TO CONTOUR MAPWORK.

Jagger House
Kingswood College
Grahamstown

Dear Colleague,

I am in the deep end of a research investigation for an M.Ed thesis. The title of my thesis is "Graphicacy and the third dimension, an investigation into the teaching of relief on topographical maps in South African Secondary Schools.

To put it into perspective for you I would like to quote some outside thoughts on this topic.

"On the whole, children appear to read maps very poorly, hence my claim that we overestimate our success in teaching map reading skills" (R.J.B. Carswell, 1971)

"The teaching of contour-map reading is generally regarded as one of the most difficult problems the Geography teacher has to face. The ability to visualise the solid reality from the two-dimensional map often seems incapable of attainment by a majority of the class. But much of this apparent difficulty is probably due to a wrong method of approach." (Memorandum on the Teaching of Geography, 1939)

"Maps are highly selective and conventionalised representations of the real world, and their interpretation demands of pupils a considerable feat of imagination and the mastery of difficult conceptual skills." (Bailey, 1974)

"Students of all ages have difficulty in thinking in three dimensions. This is evident in their attempts to visualize the shape of the land from contour maps." (King, 1985)

"Educators say that they value maps and mapping, but the evidence of children's performance in using maps is contradictory". (Bartz, 1970)

"It is surprising that few text-books used in geographical education are in any way carefully graded in the concepts which they present to pupils." (Graves, 1975)

p.t.o.

Enough said! But what of the situation in South Africa? To find this out I have analysed syllabuses from the year dot, examined text books available, other available literature (all in all some 270 references!), set up some pilot experimental studies and I feel that I am still falling short of what I want. Mainly, perhaps, this is because it is so far, a one-man show. So as Harry says "I wish to deal you in!"

I have decided at this eleventh hour, (literally!) to ask the Grahamstown geography teachers for some opinions. Do you think it is a problem area? Do students perform well enough? Do you find introducing contours easy? etc. I have dashed off a questionnaire, which although it is structured, I hope will be flexible enough so as not to inhibit your thoughts on the topic. I do know how busy you are at this stage of the year, as I am. But despite this I am asking for your 101% co-operation. Urgency is the key because I am off to mark Matric papers on 1 December and I am moving to All Saints Senior College, Bisho soon after. The manuscript has to be complete by the end of this month. Clearly I cannot have a wide ranging survey of teacher opinions at this stage but I am relying on quality and not quantity!

I have asked you to put your name on the questionnaire but I promise you that it is just for my personal interest and I will treat your answers in strictest confidence. If you feel, however, that you would rather remain anonymous I will understand your leaving your name off, but please still do the questionnaire!
Thank you, in anticipation, for your assistance. I will happily report to at the end of this all what I recommend and have found out. My plea is "please do this task urgently".

Best wishes,

Mike Burton.

M.St.J.W. Burton

p.s. Herewith an addressed envelope to help speed up matters! Thanks.

CONFIDENTIAL

NAME ....

YEARS TEACHING GEOGRAPHY.................

The questionnaire is aimed at testing your reactions to your experience of teaching relief mapwork in geography.

For each of the questions I am looking for a direct answer and then a brief comment. Should you wish to comment more fully please do so either in writing or in discussion with me.

[A] WHEN SHOULD CONTOUR MAPWORK BE INTRODUCED?

1. Satterly (1964) said that, "doubt must be cast on the value of mapwork in the Junior school and in the early classes of the senior school." Do you agree with his view?

____

[Comment]...

....

....

....

2. Piaget suggested that children only reach a stage of "formal operational thinking" after the age of 12. This implies that they are not capable of thinking abstractly in three-dimensions and therefore should not be introduced to contours until this age. Bruner, however considered that with a careful approach and with annual 're-visiting' simple concepts could be reinforced and contours could be introduced much earlier. Which psychologist do you favour?

____

[Comment]...

....

....

3.When do you introduce contours at your school? __________

[Comment]...

....

....

....

[B] HOW SHOULD CONTOUR MAPWORK BE INTRODUCED?

4. Do your start contour mapwork with the local Grahamstown sheet and identify features on map and field?

____

[Comment]..

....

....

5. Do you use landscape models to "show" features? ________

[Comment]..

....

....

6. Do you use other aids (such as computer, film, video, OHP, epidiascope etc) to teach contour mapwork?

____

[Comment]..

....

....

7. What do you consider would be the ideal programme of methods for teaching contours?

....

....

[C] TEXT BOOKS

8. Which text books do you use when teaching contours?

____

[Comment]..

....

....

9. What is your assessment of the books that are available to help teach contour work?

....

....

....

10. Do you think the order of presentation of contour concepts is graded, sequential and suitable for the pupils to whom it is pitched in text books?

____

[Comment]..

....

....

11. Do you think a manageable A4 size mapwork textbook with suitable text and exercises set to map extracts within this book would be a necessary improvement on what is available? (1:50 000 maps 76cm x 53cm too cumbersome?)

____

[Comment]..

....

....

....

[D] EXAMINATIONS IN MAPWORK

Mapwork is a compulsory question in Matric.

12. Do you think that contour mapwork is properly tested in the final matric examination?

____

[Comment]..

....

....

....

13. Do your pupils perform well in contour mapwork or do they find difficulty?

____

[Comment]..

....

....

....

14. Evaluation of mapwork skills should be structured to test higher abilities as well as simple skills. Do you think that the Matric. mapwork exams are structured or do you think they are haphazard?

____

[Comment]...

....

....

....

[E] YOUR THINKING

Please record any other thoughts that you may consider relevant to my study of contour teaching.

....

....

....

....

....

APPENDIX E

KINGSWOOD EXPERIMENTAL TESTS.

APPENDIX E.1. (Contours and Profiles).

your age ....

boy or girl...........

CONTOUR INTERPRETATION

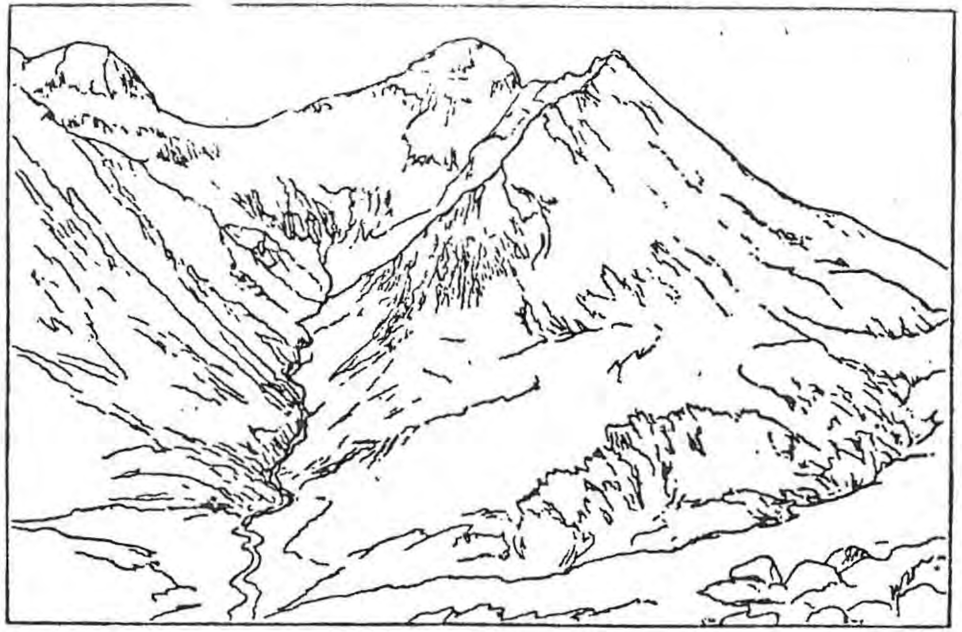
On a separate sheet of paper you will find contour maps and landscape sketch views.

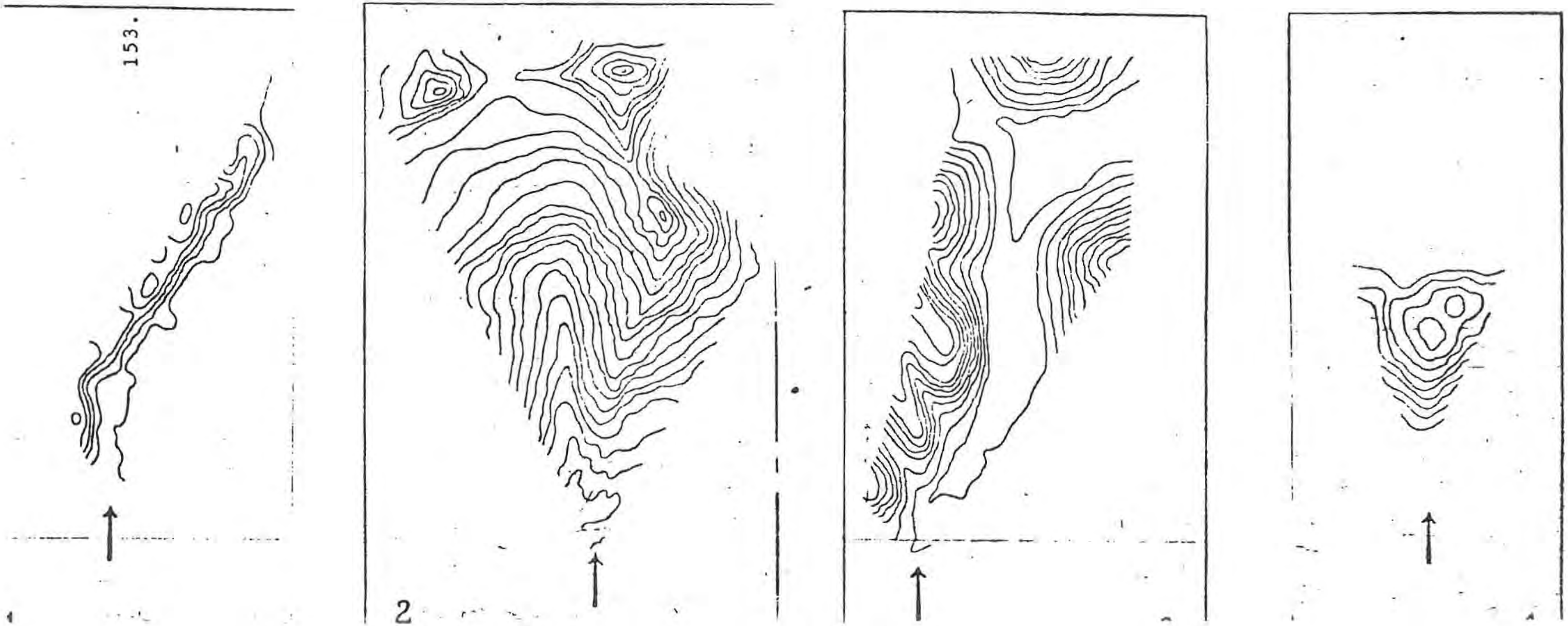
Look at Side 1 which shows four contour maps and a landscape view. Decide which map best shows the view and write its number in the block below

Now look at Side 2 which shows four landscape sketches and one map. Decide which view is best described by the map and write its letter in the block below

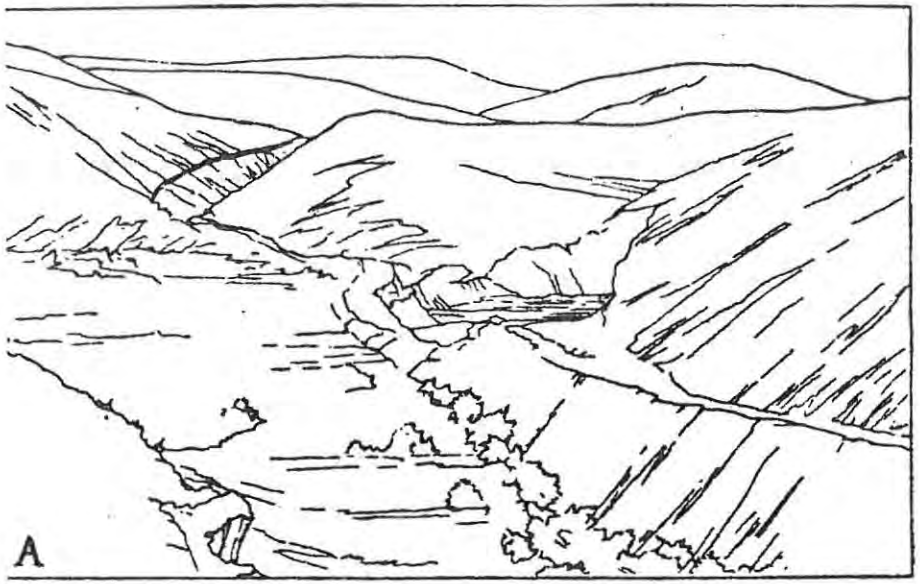
CONTOUR INTERPRETATION

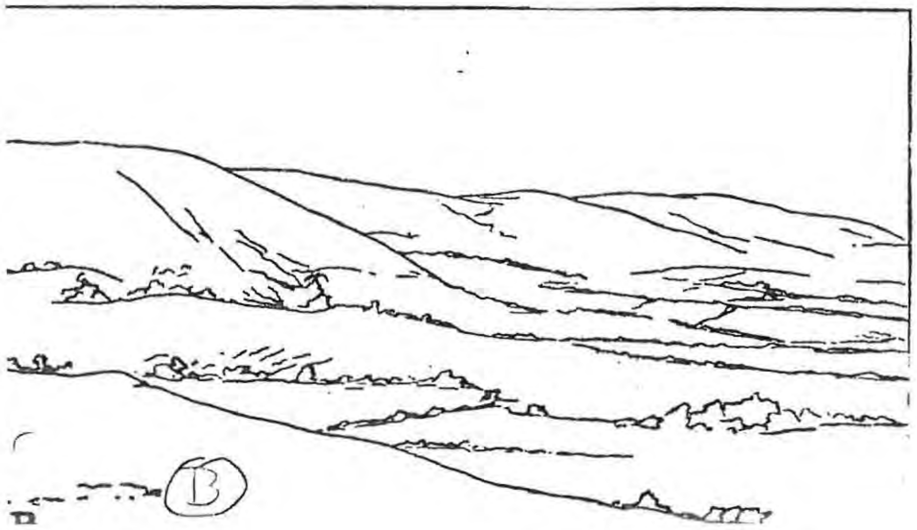
SIDE 1 FOUR CONTOUR MAPS
MARKED 1 TO 4 AND A
LANDSCAPE VIEW
(The arrows indicate the direction of viewing).





CONTOUR INTERPRETATION
SIDE 2 FOUR LANDSCAPE VIEWS MARKED A TO D AND A CONTOUR MAP.
(The arrow indicates the direction of viewing).





UNDERSTANDING CONTOURS AND RELIEF.

Age.........years

Below is a map of a piece of land with contours on it.

1. Shading
Using a crayon or pencil shade in carefully all land which is below 91 metres in altitude.

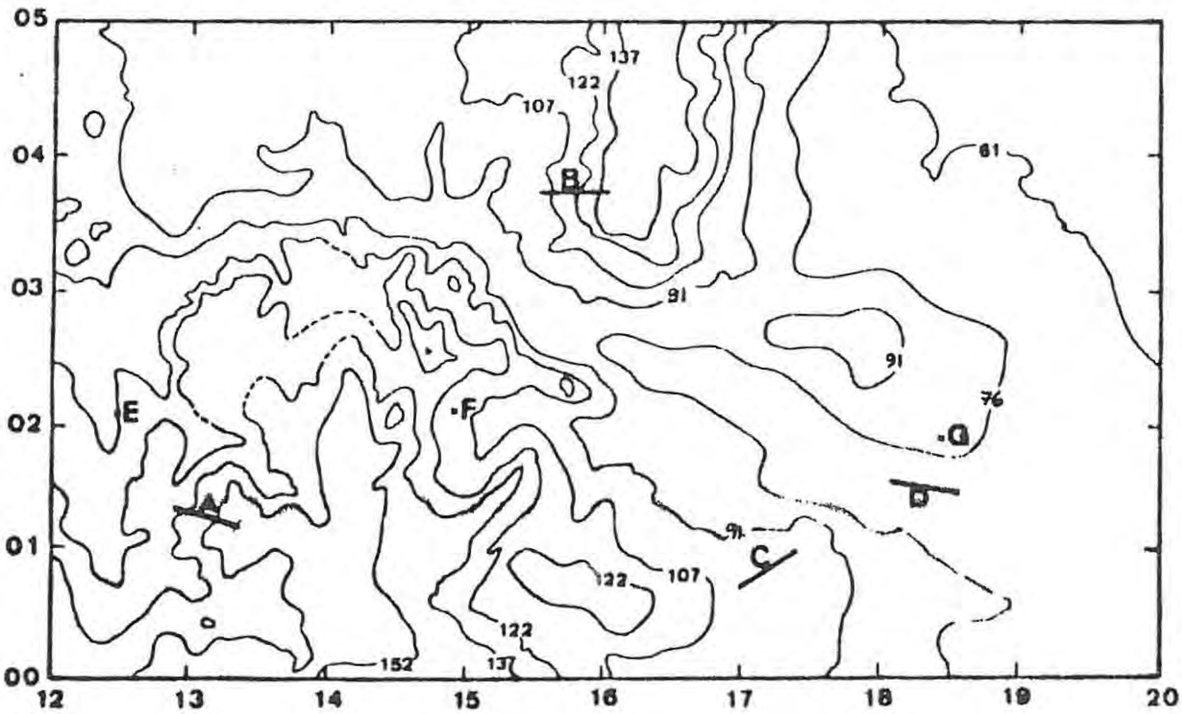
2. Higher-lower
Look at the four short lines on the map marked A, B, C, and D. Decide which end is higher on each line and draw a small circle around that end.

3. Slope steepness
Decide which of the four lines lies on the steepest slope and name that line on this space

____

4. Height estimate
Estimate the heights at the points E, f and G on the map
Write your answers on the spaces below

E____________ F____________ G____________



APPENDIX E.3.

UNDERSTANDING CONTOUR SHAPES YOUR AGE ________ years

You have 12 small numbered contour maps on the sheet of paper
Please do NOT MARK THE MAPS in any way.
Underneath each map is a series of five small 'profiles' (or side views) marked A to E.
Carefully match up the correct profile with the section on the map marked from X to Y with a line and then write your answer on the spaces next to the numbers below :

1. ______

2. ______

3. ______

4. ______

5. ______

6. ______

7. ______

8. ______

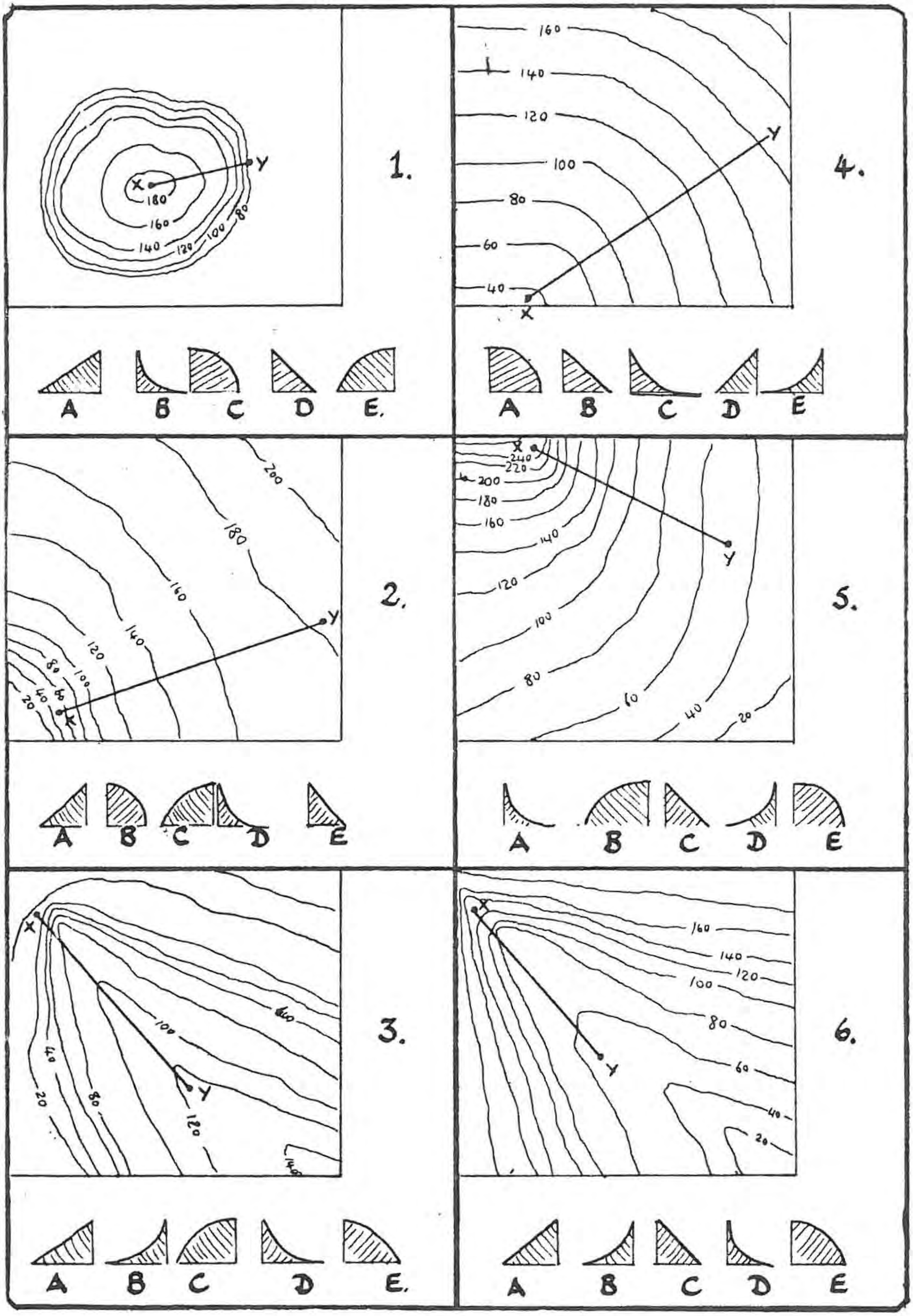
9. ______

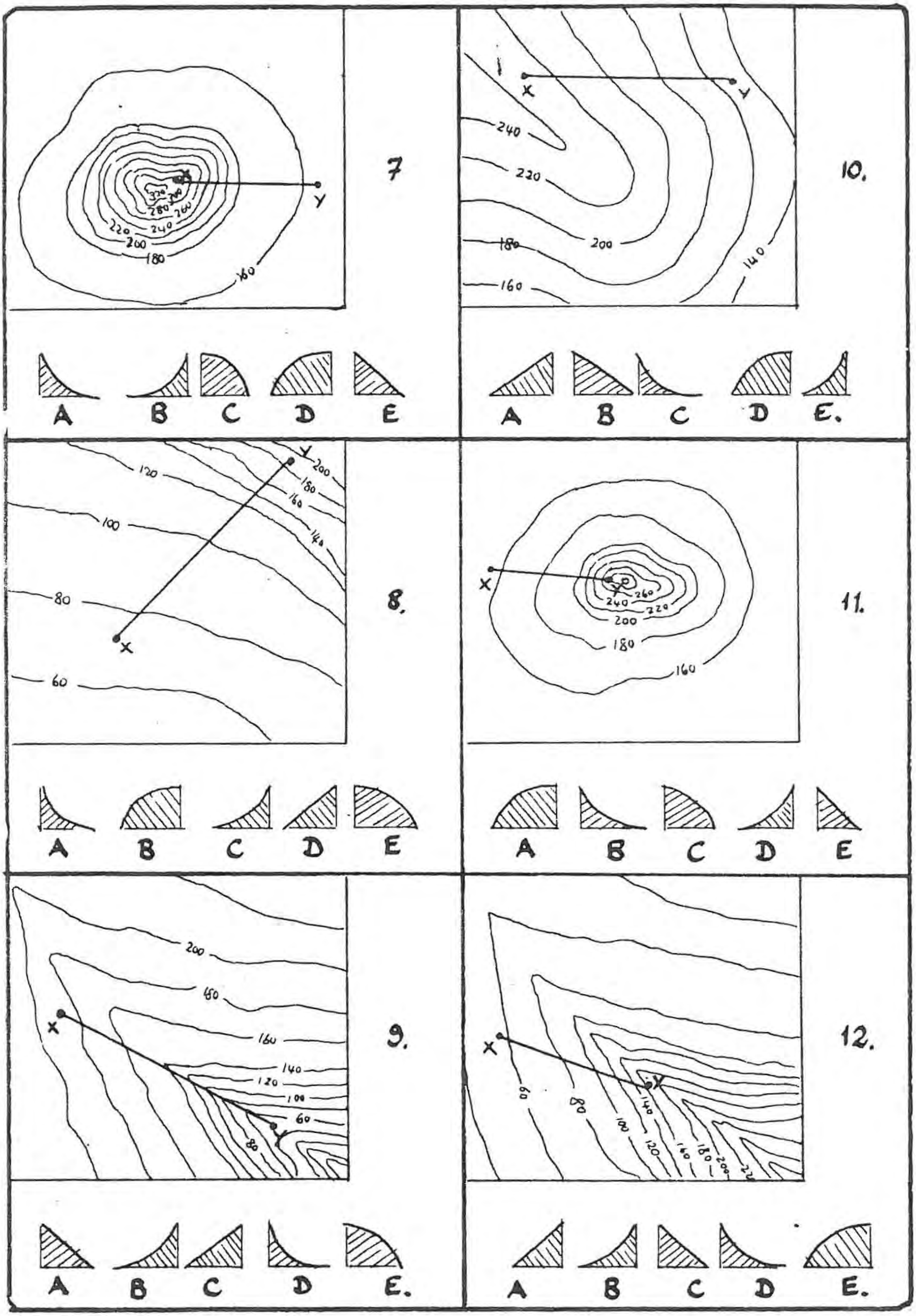
10. ______

11. ______

12. ______

(thank you)

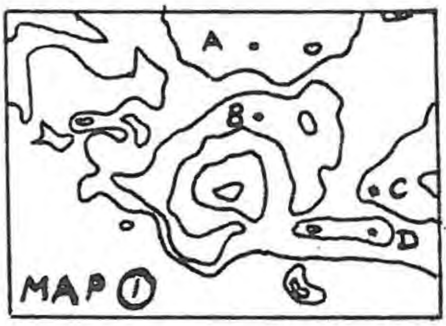

1.
X
Y
180
160
140
120
100
80
A B C D E.
4.
160
140
120
100
80
60
40
X
Y
A B C D E
2.
200
180
160
140
120
100
80
60
40
20
X
Y
A B C D E
5.
X
240
220
200
180
160
140
120
100
80
60
40
20
Y
A B C D E
3.
X
Y
40
20
80
100
120
140
A B C D E.
6.
X
Y
160
140
120
100
80
60
40
20
A B C D E

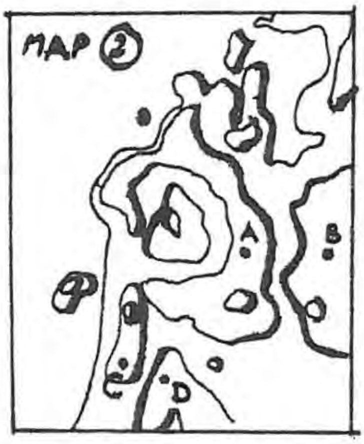

7
X
Y
320
300
280
260
240
220
200
180
160
A B C D E
10.
X
Y
240
220
200
180
160
140
A B C D E.
8.
X
Y
200
180
160
140
120
100
80
60
A B C D E
11.
X
Y
260
240
220
200
180
160
A B C D E
9.
X
Y
200
180
160
140
120
100
80
60
A B C D E.
12.
X
Y
60
80
100
120
140
160
180
200
A B C D E.

APPENDIX E.4.

CONTOUR SHADOWS

Below are three different ways of showing contours using single lines, double lines and shaded lines. On each, four points have been marked A,B, C and D. For each map you must try to decide whether A is higher than B or not and if C is higher than D or not and put a mark in the block that represents your answer.





ANSWER BLOCKS.

A & B

	MAP ①	MAP ②	MAP ③
A is higher than B			
B is higher than A			
They are the same height			
I cannot tell.			

	MAP ①	MAP ②	MAP ③
C is higher than D			
D is higher than C			
They are the same height			
I cannot tell.			

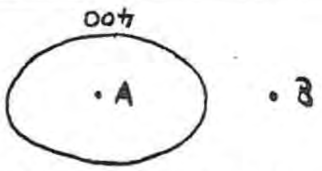
p. t. o.

CONTOUR LABELS

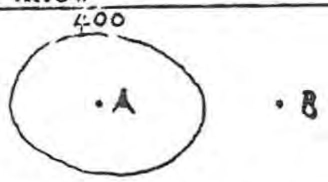
Below are eight different ways that contours have been labelled. On South African topographical maps the orientation of the label indicates higher land above the number and lower ground below the number. Imagine that the contours represented below are from a South African 1:50 000 contour map. For each put a mark in the appropriate block next to the diagram :

A is higher than B.......
B is higher than A.......
They are the same height
Don't know

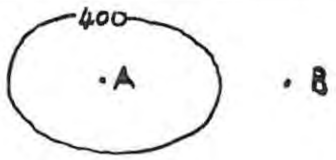
A is higher than B.......
B is higher than A........
They are the same height
Don't know



A is higher than B.......
B is higher than A.......
They are the same height
Don't know



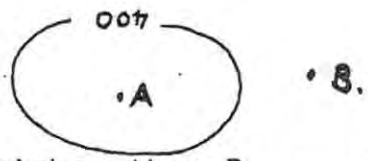
A is higher than B ......
B is higher than A.......
They are the same height
Don't know



A is higher than B.......
B is higher than A.......
They are the same height
Don't know

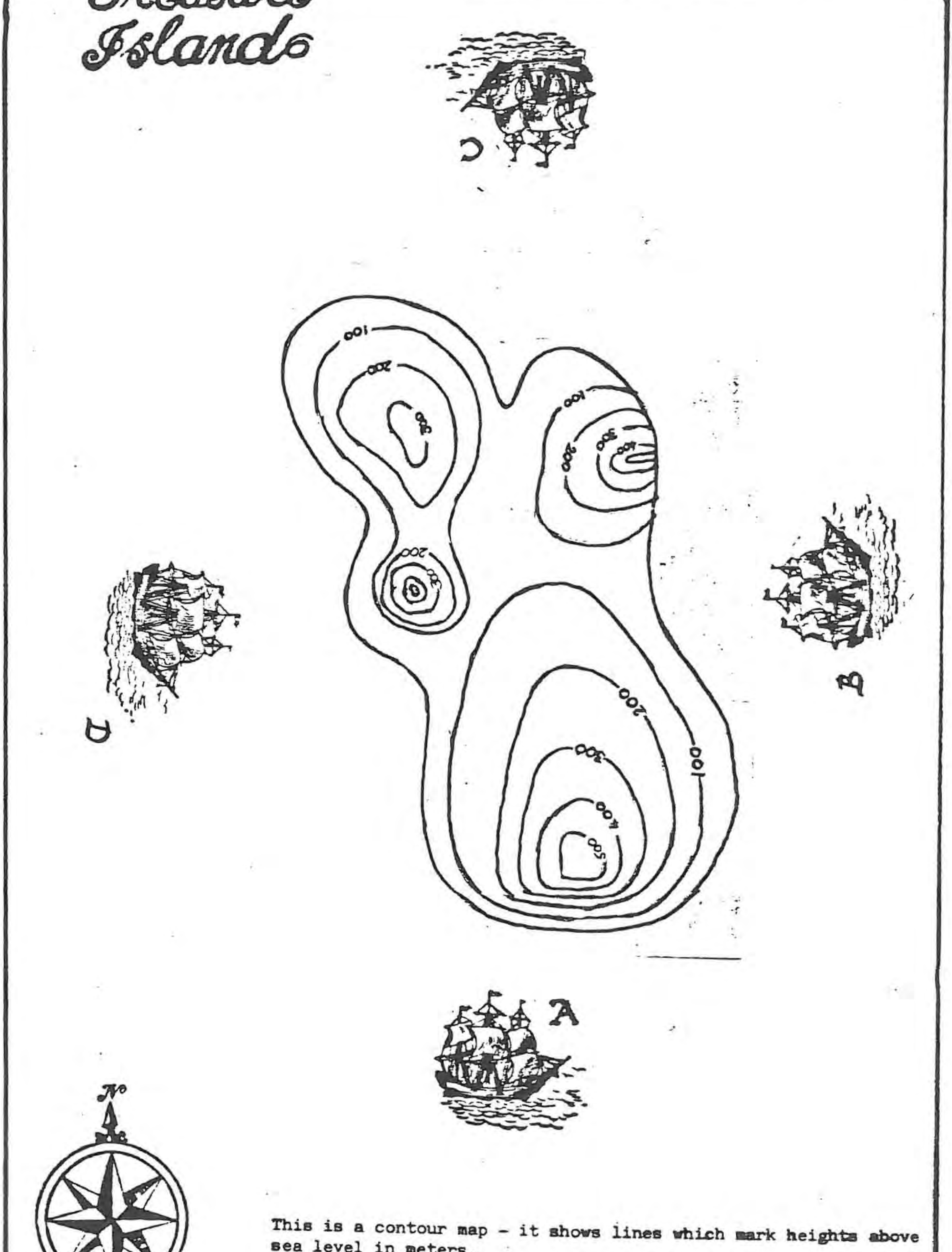
A is higher than B.......
B is higher than A........
They are the same height
Don't know

A is higher than B........
B is higher than A.........
They are the same height
Don't know



A is higher than B........
B is higher than A........
They are the same height
Don't know.

Treasure Island



This is a contour map - it shows lines which mark heights above sea level in meters.

Four galleons are circling Treasure Island (A,B,C and D).

They each have a very different view of the island and its mountains.

Use the contour map and the sheet below to try to work out the correct view for each galleon.

In each view the nearest mountains are shaded and the distant mountains are black.

Try and work out which is the correct view for each galleon from the column below and then put a tick in the box which you think is the right one.

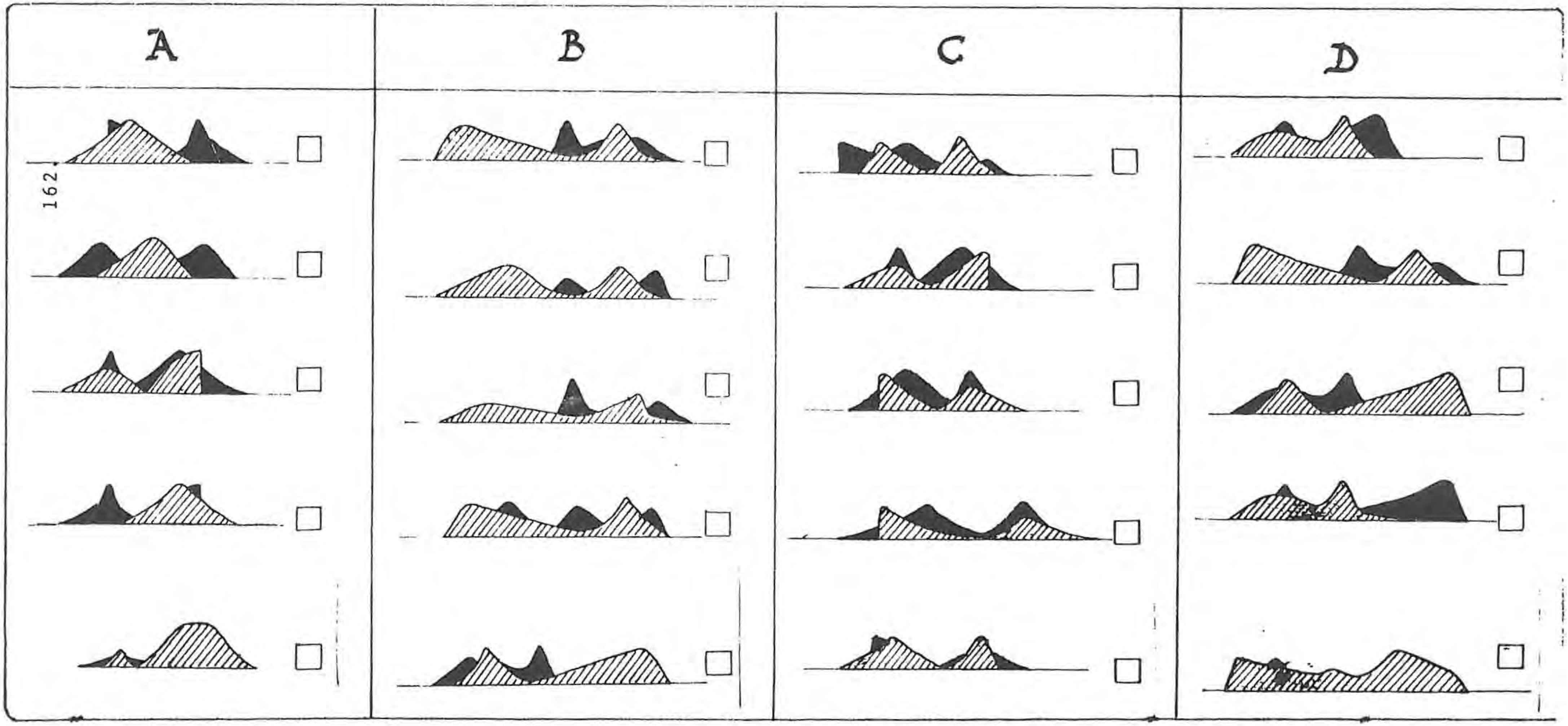
Please indicate your age .... years.

and your class STANDARD .....

Are you a boy or girl? ....

Have you ever been taught about contours in class ....

Anywhere else? ....



Your mark →

APPENDIX E.6.

CUBE EXERCISES - ROTATION AND BLOCKS Your age 14

1. Testing pairs.

Look carefully at the page with cubes.
In the first five blocks there are pairs of cubes forming different shapes. Some of these pairs may be identical, and some may be different in some way. Examine each pair and if you think thay are identical put a tick in the column marked "identical" and if you think there is some difference put a cross in the column marked "different"

	IDENTICAL	DIFFERENT
1.		
2.		
3.		
4.		
5.		

2. Number of cubes in the solid.

Blocks 6 and seven show solids made up of a number of similar size cubes. Work out how many cubes make up the total shape and write your answers below

6.______

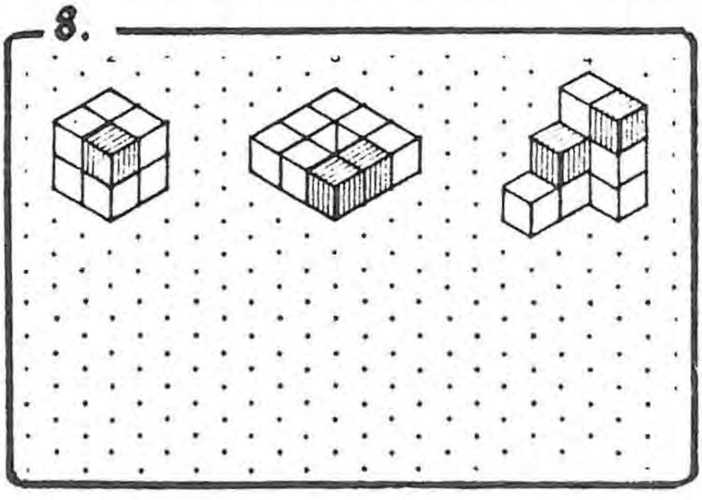
7.______

3. Adding and removing cubes.

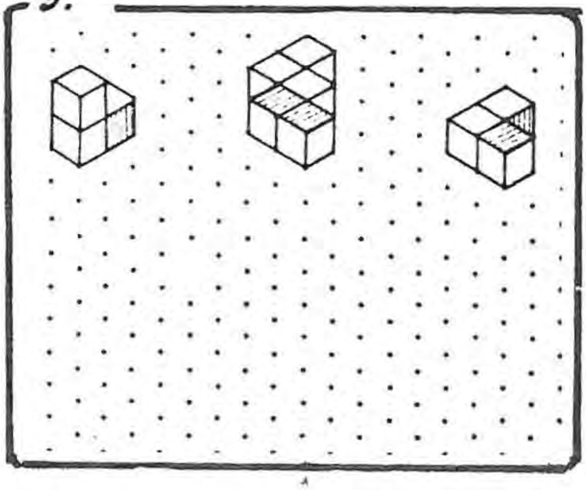
In block 8. below take away the shaded cubes and then (using the dots below) draw the new solid.

In block 9. below add a cube to each shaded face and then (using the dots below) draw the remaining solid.

8.

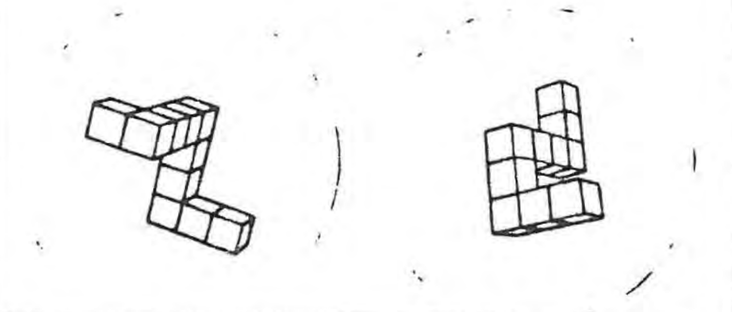


9.

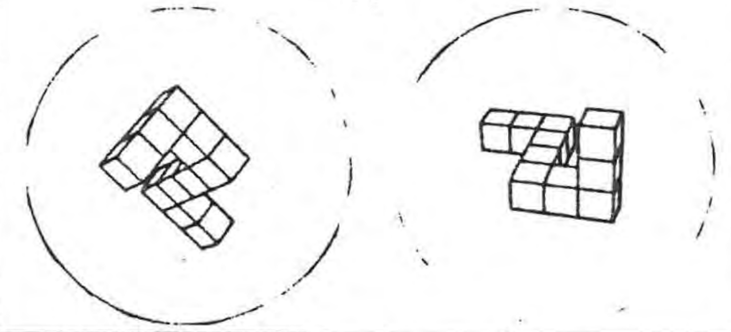


CUBE EXERCISES - ROTATION AND BLOCKS

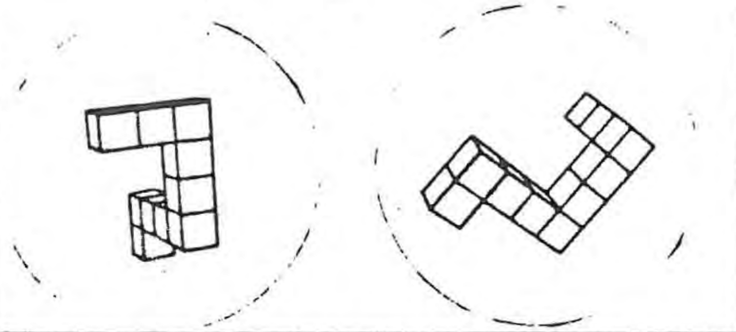
1.



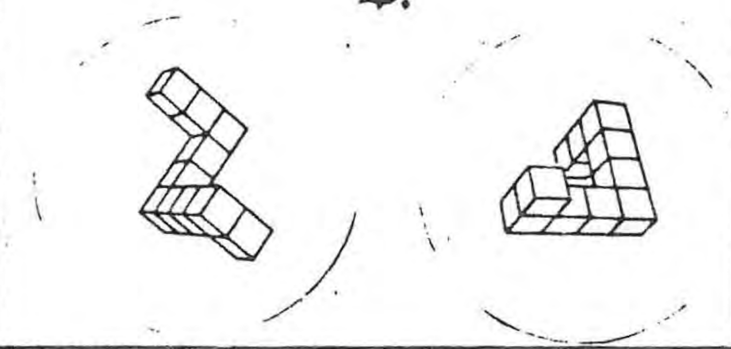
2.



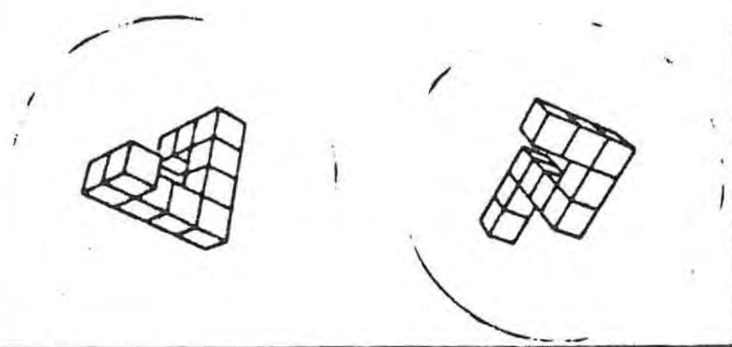
3.



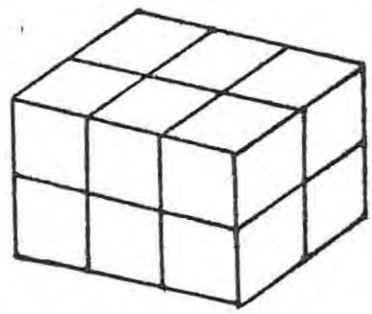
4.



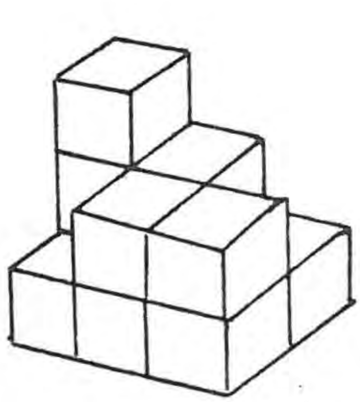
5.



6.



7.



CONTOUR MAPPING SKILLS

Your mark

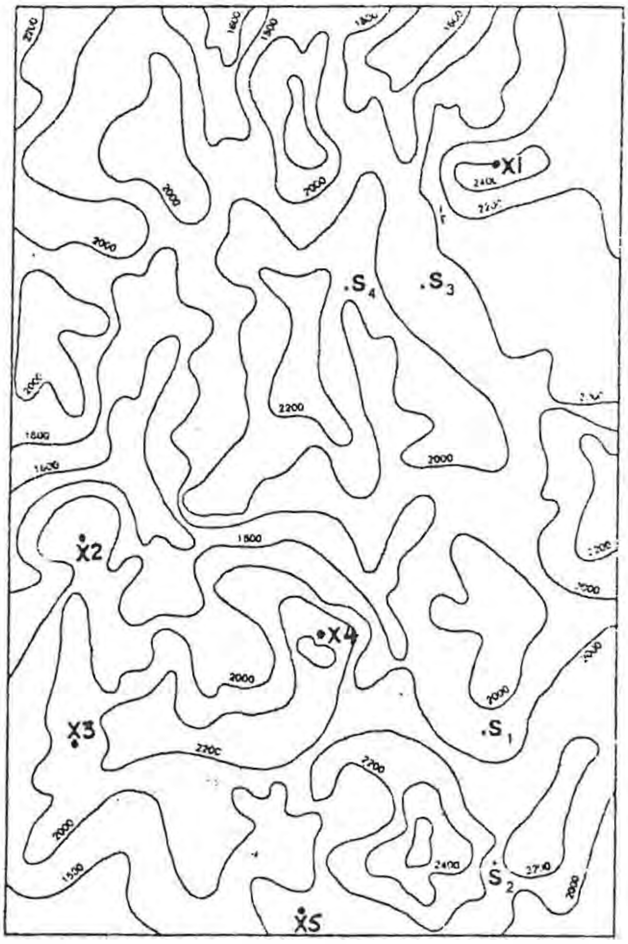
On each side of this page is a map marked MAP 1 and MAP 2 showing the same area of land. Answer the following questions:

MAP 1

1. Put a small circle at the lowest point on the map and a small triangle at the highest point.
2. Estimate the heights of the five points marked X1 to X5 and write your answers below :

X1______ X2______ X3______ X4______ X5______

3. From source areas marked S1 to S4 draw the possible courses of four rivers



MAP 2

4. Imagine that you are standing at the point O (near the middle of the map). From this point you look at a person at each of the points marked A to H. Decide whether from your viewpoint you can see each person and for each that you can put a tick on the space next to the letter and for each that you cannot put a cross on the space next to the letter below :

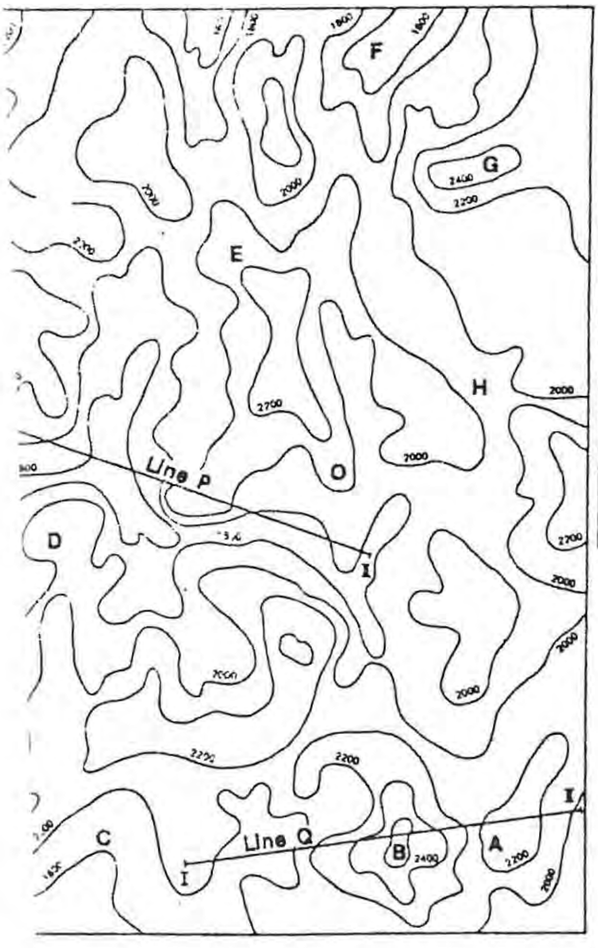
   A____ B____ C____ D____ E____ F____

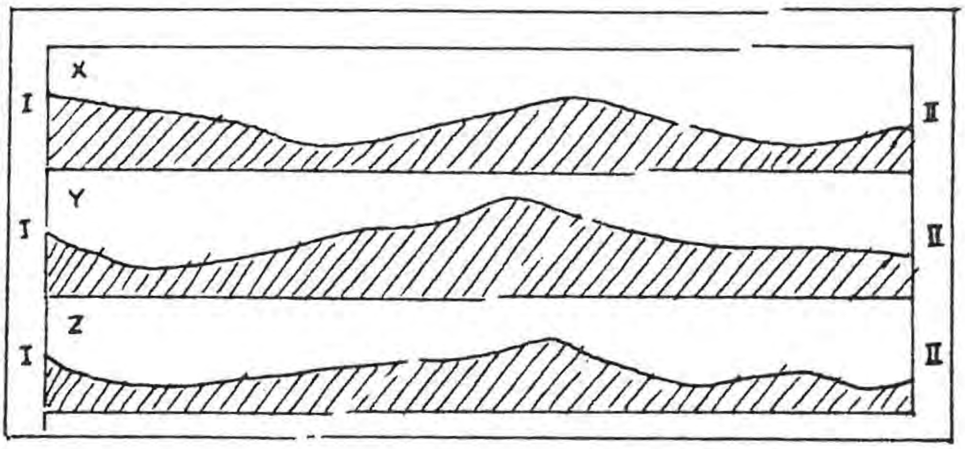
   G____ H____

5. Put a small arrow pointing to the steepest slope on the map and an X in the middle of the gentlest slope.

6. Line P from I to II and line Q from I to II can be matched with two of the three cross profiles below marked X, Y and Z
   You must decide which profile matches which line and write your answers below :

   Line P ________ Line Q ________





APPENDIX F

DATA FOR STATISTICAL ANALYSES OF KINGSWOOD EXPERIMENTS

APPENDIX F.1. Data for the statistical analysis of Experiment 1 Contours and profiles.

Statistical tables and calculations for the Pearson's product-moment correlation coefficient parametric method used to test the null hypothesis that there is no significant relationship between responses to the investigation by the Training College Group Committee of the Geographical Association (1941) that attempted to discover how far children can interpret the actual forms presented by contour lines in terms of a simple landscape, and the Kingswood (1985) experimental tests.

TEST 1

K.C. Sample Size	Age	x	y	x^2	y^2	xy
37	11	51	45	2601	2025	2295
31	12	47	49	2209	2401	2303
38	13	52	55	2704	3025	2860
28	14	57	60	3249	3600	3420
35	15	64	66	4096	4356	4224
33	16	71	75	5041	5625	5325
19	17	78	85	6084	7225	6630

$\Sigma x = 420$ $\Sigma y = 435$ 25984 28257 27057

$n = 7$ $n = 7$ $\Sigma xy^2 = 3720$

$\bar{x} = 60$ $\bar{y} = 62$ $\bar{x}^2 = 3600$ $\bar{y}^2 = 3844$

TEST 2.

K.C. Sample size	Age	x	y	x^2	y^2	xy
37	11	35	48	1225	2304	1680
31	12	50	56	2500	3136	2800
38	13	66	64	4356	4096	4224
28	14	71	74	5041	5476	5254
35	15	80	77	6400	5929	6160
33	16	74	78	5476	6084	5772
19	17	70	79	4900	6241	5530

$\Sigma x = 446$ $\Sigma y = 476$ 29898 33266 31420
$n = 7$ $n = 7$ $\Sigma xy = 4352$
$\bar{x} = 64$ $\bar{y} = 68$ $\bar{x}^2 = 4096$ $\bar{y}^2 = 4624$

x = the Kingswood correct responses as a percentage of the total
y = the correct responses as a percentage of the total as recorded in the model study of 1941.

By using the equation

$$r = \frac{\Sigma xy/n - \bar{x}\bar{y}}{s_x s_y}$$

where r is the product-moment correlation coefficient, x refers to the Kingswood scores and y to the British scores, $\bar{x}$ and $\bar{y}$ are the means of the two variables, and s_x and s_y are the sample standard deviations of the two variables the resulting r values for the two tests were found to be:

Test 1 $r = 0{,}98$
Test 2 $r = 0{,}91$

The test of significance of r, using the formula

$$t = \frac{r\sqrt{n - 2}}{\sqrt{1 - r}}$$ where n = number of pairs of scores,

with (n - 2) = 5 degrees of freedom, the probability value in Fisher's table of t is such that the null hypothesis can berejected at less than the 1% level of confidence for both rvalues.

APPENDIX F.2. Chi square test for Experiment 5 (Treasure Island)

1. observed frequency of correct responses

age	11	12	13	14	15	16	17	18	total
boys	22	17	32	40	55	48	56	18	288
girls	8	18	29	12	33	30	5	3	138
	30	35	61	52	88	78	61	21	426

2. expected frequency of correct responses

age	11	12	13	14	15	16	17	18	total
boys	20,3	23,7	41,2	35,2	59,5	52,7	41,2	14,2	288
girls	9,7	11,3	19,8	16,8	28,5	25,3	19.8	6,8	138
	30	35	61	52	88	78	61	21	426

3. χ^2 = 0,14 + 0,30 + 1,89 + 3,97 + 2,05 + 4,27 + 0,65 + 1,37 + 0,34 + 0,71 + 0,42 + 0,87 + 5,32 + 11,06 + 1,02 + 2,12

= 36,5 →

4. Degrees of freedom, df = (r - 1)(c - 1) = 7

5. χ^2 with df = 7 is significant at the 1% level is 18,48 →

6. Reject the null hypothesis of no significant difference between the groups at better than 1% level of confidence and that therefore there is a strong reason to believe that there is a significant difference.

APPENDIX F.3. Pearson Product-Moment test for Experiment 6 (Contours and Cubes).

1. Results of responses to the cube three-dimensional thinking tests and mapwork proficiency test

AGE	n	ΣX	ΣY	ΣX^2	ΣY^2	$\bar{X}$	$\bar{Y}$	ΣXY	r
18	4	34	49	332	665	9	12	447	0,58
17	21	201	286	2151	4244	10	14	2917	0,64
16	48	439	579	4457	7893	9	12	5743	0,89
15	38	335	383	3419	4891	9	10	3702	0,61
14	38	322	407	3232	5311	9	11	3923	0,83
13	39	254	271	2004	2503	7	7	1969	0,44
12	39	192	162	1202	966	5	4	790	-0,03
11	37	197	176	1361	1364	5	5	1126	0,46
10	6	36	27	246	167	6	5	135	-0,73
	270	2010	2340	18404	28004			20752	

n = sample size
ΣX = sum of scores for the cubes tests
ΣY = sum of scores for the mapwork tests
$\bar{X}$ = mean scores for the cubes tests
$\bar{Y}$ = mean scores for the mapwork tests
r = correlation coefficient value

2. To find the correlation co-efficient,

by using the equation $r = \frac{EXY/n - XY}{s_x \ s_y}$

Where r is the product moment correlation coefficient, X refers to cubes test scores, Y for the mapwork test scores X and Y are the means of the two variables, and s and s are the sample standard deviations of the two variables the resulting r value was found to be: 0,65

3. The test of the significance of r using the formula $t = \frac{r\sqrt{n-2}}{\sqrt{1-r}}$ where n = the number of pairs of scores, the value of t was calculated as 14,03
With n - 2 = 268 degrees of freedom, the probability value in Fisher's Table of t is such that the null hypothesis can be rejected at less than 1% level of confidence.

Appendix F.4. Chi-square test for Experiment 7 (Rubik Cube and Profiles)

1. Observed frequency of correct responses

CARD	AGE IN YEARS 16	15	14	13	12	11	TOTAL
1	25	24	22	15	5	5	96
2	39	36	36	25	20	25	181
3	42	36	39	25	25	25	192
	106	96	97	65	50	55	469

2. Expected frequency of correct responses

CARD	AGE IN YEARS 16	15	14	13	12	11	TOTAL
1	21,7	19,7	19,8	13,3	10,2	11,3	96
2	40,9	37,0	37,5	25,1	19,3	21,2	181
3	43,4	39,3	39,7	26,6	20,5	22,5	192
	106	96	97	65	50	55	469

3. χ^2 = 0,502 + 0,088 + 0,045 + 0,939 + 0,027 + 0,277 + 0,244 + 0,060 + 0,012 + 0,004 + 0,096 + 2,651 + 0,025 + 0,988 + 3,512 + 0,681 + 0,278

= 10,646

4. Degrees of freedom = (r - 1)(c - 1)
= (3 - 1)(6 - 1)
= 10

5. Conclusion : the chi-square test indicates that there is no significant difference between the performances of pupils tested on the three cards.