A CRITICAL EXAMINATION OF CONCEPT ANALYSIS AND ITS APPLICATION TO CONCEPTS OF SPACE IN GEOGRAPHY

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PREFACE

Concept analysis utilising Piaget and Gagné's theories is an expanding area of research in the 'exact' sciences such as physics and chemistry. It is, however, new to the concepts in geography which are 'non-exact'. The thesis, then, is an exploratory study; and concept analysis is considered a possible methodology for examining the students' understanding of non-exact geography concepts.

The thesis is divided into two parts. The first contains an examination of the theory of concept analysis and a critical review of empirical studies, with a view to applying concept analysis to the discipline of geography. The second part involves what has been termed a case study, where concepts are selected for analysis, and students were tested for their understanding of the concepts. The study as a whole is complex in structure, and several points require clarification at the outset.

1 The study takes on an approach which centres on discovering problems, where the emphasis is on revealing the methodological difficulties encountered and on identifying the misunderstandings of students. Such a focus is advantageous because it brings to the fore, areas where some form of change needs to be made, or research conducted. Due to the approach taken, much space is devoted to a review of literature and the questionnaire construction. Research in geography can benefit from previous research experience in other disciplines. The questionnaire is central to the study because in the first instance it influences the responses elicited, and in the second instance it is the beginning of working toward the development of a test which is useful for application by teachers to ascertain their students' understanding. It needs to be stated here that the aim of the study is not so much to test the validity of Piaget and Gagné's theories, as to test their use in concept analysis in geography.

2 The difference assumed between 'non-exact' and 'exact' concepts, is that the former often cannot be as precisely defined as a formula, and a single concept may be used differently by a number of researchers within the same discipline. Establishing standards for 'correct' and 'incorrect' is complex, as there can be a

spectrum of understanding, ranging from misunderstanding to adequate understanding and mastery of a concept. Although the complexity is a shortcoming, the emphasis of the study lies with the question of why the student has the level of understanding he does, rather than with whether the student is 'correct' or 'incorrect'.

3 The responses of students from one year only are examined. Although the study involves the development of reasoning ability, it is cross-sectional rather than longitudinal for two reasons. The study is exploratory, and both methodology and techniques need further research and development. A cross-sectional study can reveal the students' abilities at a particular time during their course, as in the studies by Wohlwill (1968) and Karplus and Karplus, (1970). Cross-sectional studies may be extended to longitudinal in order to establish the effectiveness of teaching methods, any remedial action implemented, and students' own developments in reasoning.

4 Many of the published studies do not give details of questionnaire construction, method of administration, or how concepts were classified as requiring concrete or formal operational thinking. These omissions make cumulative research difficult. The concepts in the present study were classified as requiring concrete or formal operational thinking through analysing the thinking processes required for adequate understanding of each concept to be tested. Piaget's theory was used as a guide. As a result, the subsequent classification of the concepts - although scrutinised by other geographers - is subject to correction.

5 A point of clarification regarding terminology is important. Concrete operational thinking is abbreviated to concrete thinking, or concrete operations. A concrete concept, is a concept which requires concrete thinking abilities for adequate understanding ; a concrete thinker refers to a student who uses concrete operations with regard to the relevent concept under discussion. The same applies for 'formal'. Also, conceptual ability is a subset of cognitive ability.

6 The term 'students' has been used when referring to general instances,

and 'student' to particular examples or tendencies. Also he/she has been abbreviated to 'he' for ease of reading. Inverted commas have been given to 'exact' and 'non-exact' in the introduction and conclusion only, in recognition of interpretations surrounding the terms.

7 During the analysis, continual reference is made to particular questions in the questionnaire. To aid reading, abbreviations of all questions are given prior to the discussion of each, in order to avoid continual reference to the appendix where the questionnaire has been included in full. However, reference to a certain item or group of students may remain confusing but seems unavoidable. Also, in the analysis small tables are used to illustrate responses to each question. These are many in number, and since each table is included immediately prior to the discussion of its contents and is not referred to thereafter, they are not given table title and numbers.

8 Finally, all numbers in the text with more than two digits have not been written in words in order to be less cumbersome.

The study, then, is largely exploratory. There is little previous research in geography by which to measure assertions and assumptions made, and with conclusions only being able to be made tentatively. The thesis begins with the introduction opening the study, outlining the procedures followed.

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CHAPTER ONE

INTRODUCTION

Interviewer: "How many dimensions does a sphere have?"
Student : "One."
Interviewer: "And a cube?"
Student : "Three ... because you can see them."

Does the second year university geography student quoted above know he does not understand what 'dimension' means? Does the student's teacher realise he does not understand, or is it taken for granted that the concept is understood? Why has the student not grasped the meaning? Is it a difficult concept? Does an understanding of the concept require a greater conceptual ability than the student possesses? Are there other students who have a similar misunderstanding? The questions are crucial and require attention if effective learning and teaching are to take place, if the concept structure of the discipline is to be recognised, and if the philosophical underpinnings of the concept are to be understood. The above and other questions are often asked of concepts in the 'exact' sciences. If the questions are of value, they need to be asked within the realm of all disciplines. Such an inquiry is called concept analysis.

Concept analyses have been conducted within the disciplines of physics and chemistry in particular, employing development and learning theories such as those of Piaget and Gagné. Little concept research has been done in geography despite the concern expressed by geographers such as Beaujeu-Garnier, (1976) and Gregory, (1978) . The present study is a response to this concern, and explores the method of concept analysis employing the theories of Piaget and Gagné in search of a possible paradigm for concept research in geography.
There are three major aims in the present study:

1. to examine methods of concept analysis conducted in other disciplines;
2. to conduct a case study of concept analysis in geography; and

3. on the basis of both, evaluate concept analysis as a paradigm for concept research in geography.

An outline of the study as a whole will serve to indicate how the research framework attempts to fulfill the aims.

The study begins with an attempt in Chapter Two to dispel any notions that 'concept' can refer to principles or is confined to pedantic arguments of semantic issues. An outline of the process of concept formation follows, and the theory behind the process is discussed. It is noted in particular that the formation is by means of a process, implying that an individual may form a concept of something but that it could be inadequate for him to have a full understanding of the meaning generally attributed to the concept. For example, the student quoted above has a concept of 'dimension', but it is inadequate for him to use the concept in the generally accepted way. Growth toward an adequate concept which he is able to use correctly needs to be encouraged. The question to ask is: Why does the student not understand? Theories such as those of Piaget and Gagné attempt to answer such a question.

Continuing in Chapter Two, cognitive development and conceptual abilities are considered in relation to Piaget and Gagné's theories. Possible answers to the question of why a student does not understand a concept are suggested by the theories. Referring to the above student, possible reasons for his lack of understanding include the following. He may be capable of understanding the concept but was taught wrongly at school; he may have misread text books, or been misled by text books; he may not have let himself be exposed to being challenged on his understanding; or he may misunderstand prerequisite concepts which prevent him from being able to understand 'dimension'. Alternatively, at his present level of ability, he may not be ready to understand the concept - in which case, instead of having no concept of dimension at all, his present concept was formed as a coping strategy. The present concept then becomes an interim measure until his conceptual ability increases to a level where he is capable of understanding adequately. As illustrated in Chapter Five, his need to picture the the dimensions in a particular way expresses a level of development insufficient for understanding. However, such coping strategies are not always helpful, since the student may find it difficult to change his concept at a later time. The theories of Piaget and Gagné are examined in terms of application in empirical studies, where individuals' responses are analysed.

Chapter Three introduces empirical studies of concept analysis, many of which draw on one or both of the theories mentioned. The studies are examined with the purpose of identifying problems, particularly those which would affect application to geographical concepts. It becomes evident that the methodologies employed and techniques used for analyses still need improving and are undergoing research. Many of the studies are exploratory, and are conducted with small sample numbers (eg. Mannino et al, 1973; Howe, 1974; Toews, 1976; Kolodiy, 1977). The sample sizes of the studies mentioned were ninety, twenty, forty seven, and twenty five respectively. The reasons for the small numbers are varied, but include primarily that they are exploratory; that interviews conducted require small numbers due to time limits, and that the studies were specifically geared for all students in a particular class or year, where the number in the group happened to be small. Although small sample sizes are disadvantageous for statistical analyses, it is evident from the experience of researchers that qualitative analyses on an individual level are necessary. This is due to the essentially ideographic nature of much of concept analysis at its present level of development.

The second part of the study involves an exploratory case study of concept analysis applied to several concepts of space. 'Space' may be seen as a unifying concept in geography which was viewed as a discipline of distance, (Watson, 1955), with geographic questions being about events in space (Sack, 1972). Also, there has been a realisation that although geography has adopted concepts of space from physics, the concepts have not been given the attention in geography that they have in physics (Sack 1973). The result has been that the explanation and use of the concepts have been imprecise and used differently by separate researchers (Meyer, 1977). If there is an element of confusion amongst geographers regarding concepts of space, what concepts do the students form in response to the lack of clarity and contradiction in literature? The question is addressed in Chapter Four where concepts of space are outlined, and a selection of concepts made for the case study. The methodology adopted is given in detail. Much space is afforded to the methodology since it lays the foundation for the case study and determines its validity and reliability. It is in the area of methodology and techniques chosen that difficulties need to be exposed and possible direction given for improvement. Following the research design, data are collected and analysed.

Chapter Five contains a detailed analysis of the data. The detail is in part due to the study being both nomothetic - assessing the students' performance against standards of acceptable concept definitions and looking for trends, and ideographic due to the inherent individuality of learning and learning difficulties. By no means have all the possibilities for analyses been exhausted, or the implications of different responses been expounded.

The questionnaire which is used along with the interviews to elicit responses contains a wide range of questions. It would be difficult to reduce the range and number of questions within the questionnaire in an attempt to do a greater in-depth study of fewer responses. The range is necessary to include questions testing definitions of concepts; students' use of the concepts in solving a problem; and conceptual abilities of students about topological, projective and Euclidean space, and cognitive development. The number of questions is the minimum required by the statistical technique used - at least two questions for each concept of space. More on the theory and rationale behind the questionnaire is included in the section on methodology. Responses to the questionnaire are many and varied, and analyses were carried out to the extent that the methodology is explored, and the types of responses yielded were examined, before tentative conclusions were drawn.

In the final chapter, the possibility of a dual-base of theories of Piaget and Gagné in concept analysis as a paradigm for geography is considered. Both the critical examination of concept analyses in other disciplines, and the case study on concepts of space in geography are reviewed. Concept analyses in past research in other disciplines are viewed in terms of problems and limitations, the present case study is examined and suggestions are made for improvements of the study and the direction of future research is accepted as being dependent upon past and present studies.

CHAPTER TWO

CONCEPTS, COGNITION, AND CONCEPTUAL ABILITIES

Feldman (1971) suggested three basic issues which are involved in studying concept formation. The first issue concerns the actual process of concept formation; the second involves analysing the various stages of development in thinking processes; and the third issue pertains to the organisation and structure of the conceptual system. The first item will be discussed in the first section of this chapter in terms of the concept formation process and the relationship between conception and perception. The second and third issues will be considered in the second section on Cognitive Development and Conceptual Abilities.

A. CONCEPT FORMATION

A note on the use of the term 'concept' is necessary at this point. The term 'concept' is often used in literature to refer to principles, or semantic issues of noun labels (Platt, 1963). Imperatore (1970) demonstrates this to be the case in geographic literature by drawing on various authors' statements. The difference between concept and principle is exemplified by Cantu and Herron (1978) who point out that 'hydrocarbons' is a concept, and 'hydrocarbons burn' is a principle. On the other hand, concept is not to be equated with label. The ordered formation, as referred to by Klausmeier et al (1974) in their definition of concept, needs to be communicated. A term or label needs to be selected. Rice (1967, p.2) suggests that "...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 would appear to equate words with concepts, when it is rather the ordered information which comprises the concept. Although language is important, should the term or word used to communicate the particular categorisation of information be changed arbitrarily, the concept itself would remain unchanged. Concept formation then, is more than a semantic issue. It is concerned with the process of acquiring characteristics of a concept which enable information to be ordered or categorised. The steps involved in concept formation need to be outlined before distinguishing between concept formation and the related process of perception.

1. The process of concept formation

The findings of Bruner, Goodnow and Austin (1956) stress two difficulties associated with the process of concept formation. The first lies in analysing a process which is essentially subconscious and therefore largely unobservable. The second concerns the question: how does a person know when a concept has been learned in a serviceable way? The following discussion will centre around the two difficulties expressed.

Concept formation is that process which culminates in the attainment of a concept, and refers to patterns of thought involved in the process. The acquisition of a concept in terms of the ability to use the concept correctly may appear to be sudden, but the formation process may extend over almost any length of time. Concepts are formed as a result of experience, imagination and memory, each concept thereby being based on interpreted fact (Lowenthal, 1961; Harris, 1975). Abler, Adams and Gould (1972) combine two independently derived schemes by Margenau (1961) and van Duijn (1965) illustrating the formation of concepts from interpreted fact (Fig.1). The P-plane represents

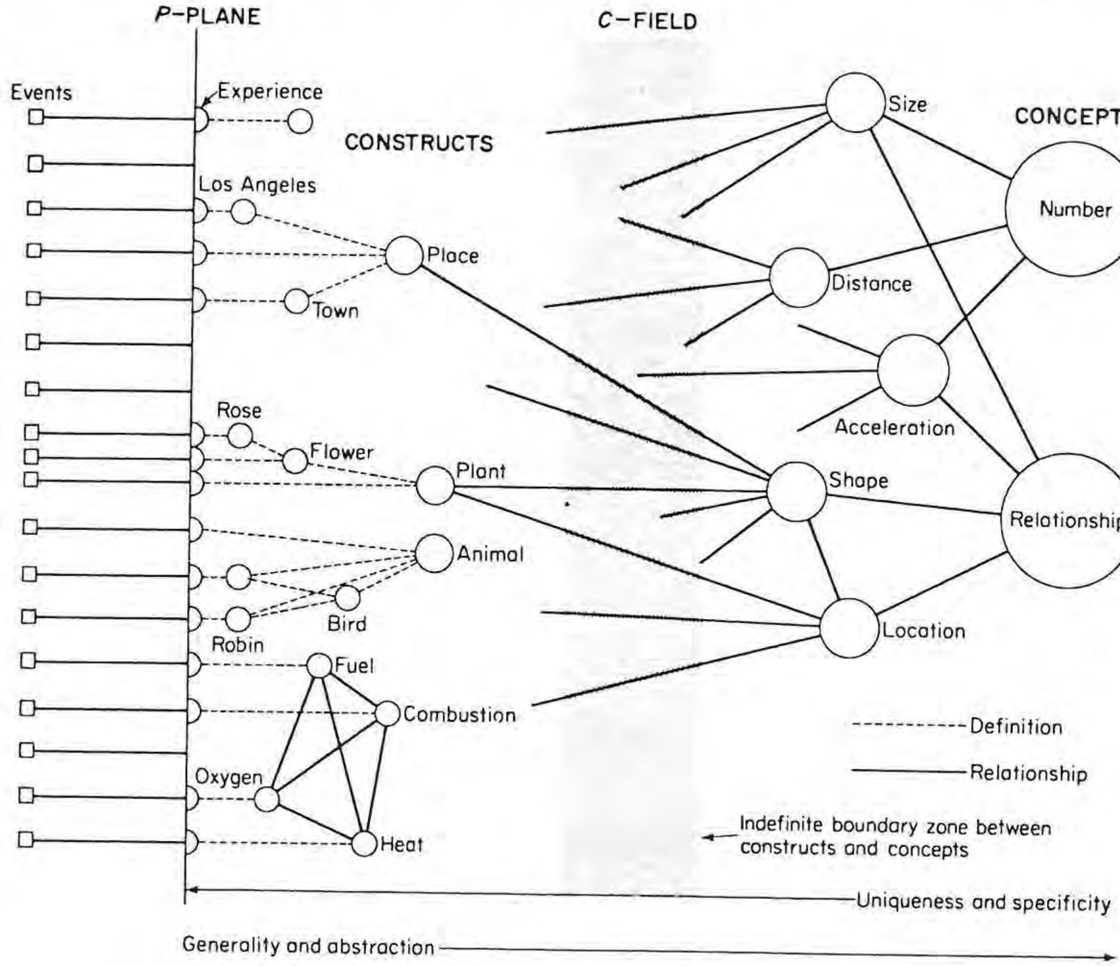


Figure 1: P-plane and C-field (Abler, Adams and Gould, 1972, p.13).

the plane of perception. Those events or instances which remain unperceived do not pass the boundary of the individual's P-plane. Those events which are perceived are ordered into constructs or preliminary categories. The C-field represents the transition from construct to concept. Concepts, unlike constructs, represent ordered identifying information about the properties of events or objects.

An example may serve as an illustration of observable changes which take place in the formation of a concept. In introducing a student to the concept of squatters, a specific example of a squatter area may be described verbally or visited. The student may note a few characteristics such as low standard of housing, low employment rate, overcrowding, and predominance of low socio-economic groups. As the student encounters other residential areas, on the basis of his initial understanding, the student may begin to categorise the areas as examples and non-examples of squatter areas. During the early stages, the student may understand the concept only in terms of specific squatter settlements, and not be able to generalise or hypothesize characteristics of squatter areas. As the student experiences feedback on his understanding either from literature or a teacher, the concept will be clarified and become more accurate. For example, once the student recognises that squatters are illegal occupants of land, he will no longer consider ghettos as possible exemplars of the concept.

Bruner (1964) suggests that learning takes place by means of a spiral process. Concept formation, being the learning of a concept by an individual, may therefore be understood in terms of a spiral process. A possible spiral process of learning the concept of squatters is illustrated in Figure 2. With learning experience, the student will mentally return to attributes continually to clarify, eliminate, or add to them. Each time the student returns to the attributes, he returns at a higher level, having progressed in his understanding of the concept. At level I, the students' concept is understood in terms of a particular example of a squatter area. By level II the student has a more refined understanding, realising which attributes are critical or irrelevant. The student may be able to use experience and memory in conjunction with imagination, to decide on inclusion or exclusion as exemplars of residential areas not directly experienced. Such a process will occur over time and cognitive development may be required for progress. Age, cultural background, and education are further possible factors which influence the progress of concept formation. These factors will be dealt with later in discussion of conceptual abilities. Experience, imagination and memory all contribute to the subjective interpretation of facts relating to squatters, and to the process of the student's understanding of the concept.

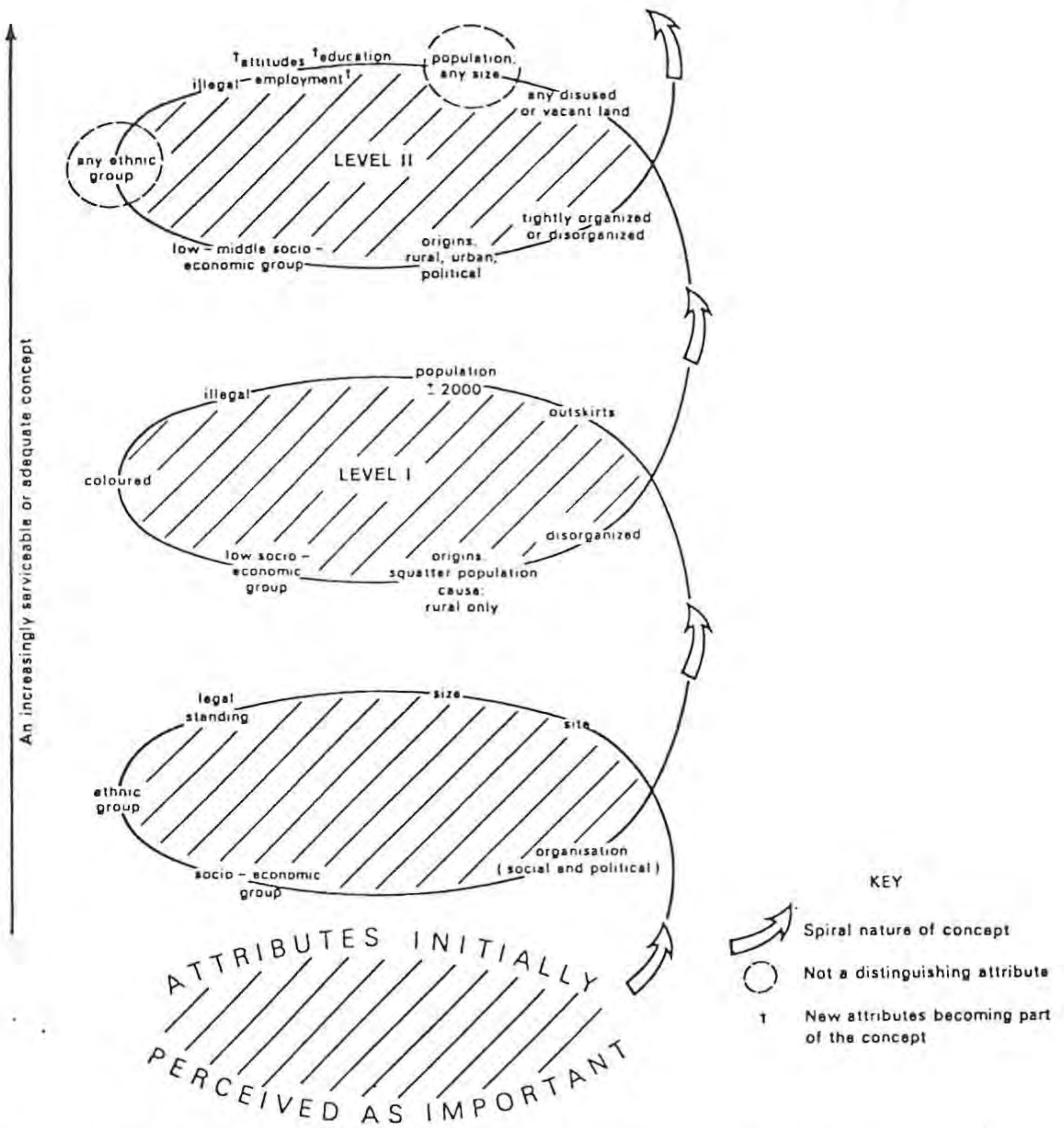


Figure 2: An example of spiral process of learning for the concept of squatters.

The question arises with reference to Figure 2, as to whether the spiral has a point of termination due to the adequacy of understanding of the concept. The problem of a student knowing when he has an adequate understanding, is introduced - the second difficulty expressed by Bruner, Goodnow and Austin (1956). A number of issues arise with regard to the problem of adequacy:-

a) Can a concept be understood by an individual to the extent where refinement is no longer necessary? This is sometimes referred to as concept mastery.

b) How does a student know at what point in the spiral process he understands the concept in a serviceable way?

Both questions concern concept attainment - the end product of concept formation.

Jammer (1969), suggests that concepts are open-ended, since:-

a) An individual's understanding can always be improved.

b) The concept itself may be redefined in the light of new discoveries by the proponents of the concept.

Indeed, it would appear severely limiting should a concept be so defined as to be considered closed. In such a case, any new knowledge would be interpreted only in terms of the already accepted concept, not allowing for any modification of the concept. How then does a student know whether he has reached a level of understanding which allows the concept to be used in a serviceable way? Markle and Tiemann (1970), and Klausmeier et al (1974) infer that a concept is 'known' and therefore serviceable if the student has the ability to discriminate exemplars and non-exemplars of the concept as presented instances. However, presupposed in such an inference is the availability of reliable feedback in the form of literature or instruction. The requirement for a reliable feedback system is that the meaning of the concept be clear in the literature or form of instruction. This point is extremely important in the study of individuals' concepts, and is raised again in a later section. Thus far, suffice it to say that if there is confusion in the potential feedback source, estimation by a student of the adequacy of his understanding of a concept is difficult. No clear standard or measure is available. Consistency between authors of meanings attributed to a concept may be resorted to as a measuring stick (Imperatore, 1970). In which case, however, it is necessary to note that consensus in itself is no criterion for truth. Although consensus of meaning aids communication, the common meaning attributed to a concept may be neither correct nor adequate. It becomes essential to strive for clarity of concepts in literature and instruction in order to enable adequate feedback and facilitate the correct use of concepts.

Indeed, still further clarity is needed of the steps involved in concept formation. An increase in knowledge would facilitate teachers' understanding of the process, the development of improved instruction techniques, and the defining of the relationships between related processes. One aspect of concept formation briefly referred to in the discussion of Figure 1, is the process of perception. The above section has outlined what is involved in concept formation as revealed by research to date. On the basis of present understanding, the following section defines the relationship between concept formation and perception.

2. The relationship between concept formation and perception

There are three major trends of thought among theorists on the complex question of the relationship between concept formation and perception:-

a) There is a predominance of perception over the process of concept formation (e.g. Koffka, 1924). The main criticism of this viewpoint is that it ignores the ability to develop conceptually whilst perceptual abilities remain unchanged.

b) Perception is governed by the principles pertaining to conceptualisation (e.g. Bruner, 1957). Diametrically opposed to a), the dominance of concept formation is a commonly held view.

c) Unlike the previous two, this viewpoint emphasises the difference between concept formation and perception rather than explaining one in terms of the other. Perception and concept formation follow separate and largely independent courses. Brunswick (1956) and Piaget (1956) are examples of those who hold this view.

Piaget (1956) further clarifies his position by pointing out that conceptual development is characteristic of intellectual and not perceptual development. In summary, the common factor in the debate lies in what Butterworth (1976) considers as the main basis for distinction between conception and perception: that conception alone is not dependent upon direct experience of the senses. The distinction is important in identifying what a concept is, what the determining factors are which govern concept formation, and how systems of concepts develop. The system of concepts evident in Figure 1 illustrates a concept scheme. It is from such a scheme that an individual's pattern of thinking develops (Theobold, 1968; Graves, 1975).

To understand how particular concepts and concept schemes are developed by each individual is to understand his resultant thinking pattern. It is here that conceptual research can make a contribution and in doing so aid in the search for the origin of misunderstandings and misconceptions. It is important to reiterate here that concepts are continually revised by the individual as a result of new knowledge. Misunderstanding of a concept can hinder the revision of development of other concepts which incorporate the misunderstood concept. Conceptual research aims to reveal the reason for misunderstandings and examines the conceptual development of individuals. Conceptual development involves not only the knowledge that the student has about a concept but also the student's cognitive ability. The latter involves perception, thinking, problem-solving, and the organisation and structure of information (Downs and Stea, 1973). A student's level of cognitive development will accordingly largely determine the possibility of a student achieving an adequate understanding of a concept. Almy (1967) has argued that geographers should pay more attention to both the fundamental concept structure of geography and the cognitive development of students. Not only would terms and conceptual relationships be clarified but the introduction of concepts could be arranged in accordance with students' cognitive ability. Such strategy appears important at any level of education, yet both White (1973) and Catling (1978) have observed that most British and American geography courses tend not to be based on any development or sequence of concepts from the simplest to the more complex. It appears that such course structure would pay little attention to differing cognitive abilities, and further indicates the need for research in concept formation in geography. Cognitive and conceptual development need to be discussed in detail, in order to ascertain fully the relevance of cognitive and conceptual research in education and in understanding the conceptual structure of the discipline.

B. COGNITIVE DEVELOPMENT AND CONCEPTUAL ABILITIES

Analysing the various stages of development in thinking processes was mentioned previously as the second basic issue in concept formation research suggested by Feldman (1971). The issue will be discussed with particular reference to Piaget's (1952) theory of cognitive development and the relatedness of conceptual abilities. Feldman's (1971) third and final issue concerns the organisation and structure of the conceptual system, and will be elaborated and explained in terms of the work by Gagné (1966).

1. Research context

The importance of relating subject-matter to cognitive development in education has been realised by Schwab (1962), Ausubel (1963), Bruner (1966) and by geographers such as Hart and Moore (1973) and Catling (1978). Yet few attempts have been made in geography both:-

a) To understand the fundamental concept structure of the discipline.

b) To link the concept structure of the discipline with the cognitive development of the student, particularly at the tertiary level of education.

Such attempts would not only contribute to the knowledge of geography's concept structure, but would also require that the student's ability to understand certain concepts be known by the teacher and curriculum developer.

Although there is absence of a generally accepted theory of cognitive development, it is agreed that cognitive development is the development of conceptual readiness of the student (Bacon, 1970). Cognitive structure is then understood as consisting of a set of concepts, called a concept structure (Rietman, 1965). In turn, a concept structure may be described as a network or hierarchy of concepts (Preece, 1976). Cognitive growth of an individual determines his readiness to understand concepts of differing degrees of difficulty or abstraction at various levels in a concept hierarchy. One of the most important debates in educational method centres on the relative efficacy of varying methods of subject matter presentation (Feldman, 1971). One of the central issues in presentation is that of learning sequences - a complex question about which no consensus of viewpoint is apparent. The two viewpoints of Piaget and Gagné are perhaps the most widely adopted in the research context of concept structure and education. The following section will deal with the theories only, whilst in the following chapter research applications and contributions of the theories to concept research will be reviewed.

2. Piaget's theory of cognitive development

Piaget's autogenetic theory is more comprehensive and detailed than other theories of intellectual development such as that of, for example, Vygotsky (1962). And whilst Nagel (1961) and Kuhn (1962) have provided detailed theoretical analyses of concept structure of knowledge and science, their work does not reveal any information on how concepts are learned. Piaget's theory sheds light on the areas of cognitive development, conceptual abilities and concept structure.

However, many experts in the field of cognitive development (e.g. Feldman, 1971; Hart and Moore, 1973) have commented on the difficulty peculiar to Piaget's theory of giving a brief description due to the theory's complexity, comprehensivity and pioneering nature. The following summary of the main Piagetian tenets is therefore recognised as limited, serving only as an introduction to Piaget. The more relevant sections of the theory for concept research will be further elaborated in the review of literature in the following chapter on Concept Analysis.

There are three basic tenets in Piaget's theory:-

a) Cognitive growth proceeds in a series of stages.

b) These stages occur in an invariant sequence, and in the same order for each individual.

c) Each stage is characterised by the ability to perform certain tasks; and an inability to perform on others.

Table 1 outlines the stages ranging from the sensori-motor period, through concrete operations to finally formal operations. The concept abilities characterising each cognitive stage are listed. Concrete and formal operations in Table 1 can be summarised in terms of two broad definitions. Concrete operations include reasoning only about the specific content of a problem; formal operations involve the individual separating the variables of the problem, and considering the possible values each might have (Levine and Linn, 1977). There is a complex process by which an individual progresses from a low stage to a higher stage. Growth in terms of age does not alone determine the cognitive stage to which an individual belongs. Many factors have been found to influence cognitive maturation, such as culture, IQ, experience and environment (Benefield and Capie, 1976). These factors will be discussed more fully in the following chapter. The process by which an individual progresses is influenced by these factors, and is termed by Piaget as equilibration. Equilibration is comprised of:-

a) Assimilation - the internalising of input from the environment through the senses.

b) Accomodation - a subsequent adjustment of the previous knowledge to integrate the new input.

SENSORIMOTOR PERIOD	CONCRETE OPERATIONS PERIOD				FORMAL OPERATIONS PERIOD
	Pre-conceptual substage	Intuitive substage	Concrete operations substage		
0-18 months	18 months-4½ years	4½-7 years	7-12 years		12 years+
Begins to know immediate environment factually, and visually.	Beginning of symbolic representation: words, actions, drawing, writing.	Simple descriptive concepts based on experience of environment.	Can manage more complex concepts and learn to deal with concept hierarchy.	Difficulty in arguing from verbal propositions.	Able to think in a hypothetico-deductive manner.
Develops ability to repeat actions	Not able to form concepts - is inconsistent.	Difficult to review a situation mentally - needs the object of discussion present.	Can review a situation mentally.	Tend to reject a premise which seems to contradict their experience. -Cannot easily conceive of an hypothetical situation.	Problems may be solved by internal processes of thinking, and physical experiment, rather than by trial and error.
			Able to arrange data according to size.		
		Thinking is egocentric -difficult to conceive of a situation in which they are not involved.	Can grasp symmetrical relationships.	Does not understand the meaning of general laws. -Cannot explain in terms of a general principle theory or law.	Inductive thinking - regularities or laws may be inferred from evidence provided.
		Difficult to understand relationship between the part and the whole.	Classify things according to two or more criteria.	Cannot easily give verbal definitions - difficulty in explaining what "the general case" is.	Becomes aware of need for, and importance of precision in defining concepts in terms of attributes as a class of objects or ideas.
		Experience difficulty with relative terms.			Can conceive mentally of "relations between relations" - multivariate situations.

Table 1. Piaget's model of mental development

(Adapted from Beard (1969), and Graves, (1975)).

Equilibration is not a static state, but rather an active process (Good, 1977). Any interaction between an individual and his environment involves equilibration, thereby constructing concept structures by which the person understands and finds order in the environment. Concept structures then, are not a product of age but rather of equilibration which determines cognitive maturation. The question arises at this point as to what the educational implications are of the theory of stages and equilibration.

There are several educational implications of Piaget's theory. Sayre and Ball (1975) illustrate one of the main implications, by pointing out that an individual cannot understand a particular piece of information unless he has concept structures which allow assimilation of the information. An explanation is thus provided as to why scientific method cannot be taught successfully to a child in the preoperational stage - he does not yet possess the necessary structure. Following on from this example, Piaget's theory has implications for discipline clarification, curriculum development and educational problems. Three questions listed by Hooper & Sigel (1968) in reference to the liason between cognitive level and teaching also summarise the above implications:-

a) When should certain content be taught?

b) What content is most important?

c) How is the content best presented?

Embodied in these three questions is the need for teachers and curriculum designers to be able to ascertain the concept structures demanded of the child or student by different concepts. Such an exercise is not simple, as is apparent from the dialogue between Phillips (1977) and Blake et al (1976), and requires a clear understanding of Piaget's different stages.

There are difficulties and criticisms associated with Piaget's theory, some of which are discussed in the survey of research in the following chapter. Despite the difficulties, however, Piaget's theory is seen as a potential research paradigm (Brady, 1970). From the above limited discussion on the theory, it is evident that the invariance of stages implies the early stages to be prerequisite for the later stages. The relationship between stages is therefore hierarchical. According to Gagné (1966) the organisation and structure of conceptual systems is hierarchical. The theories of Gagné and Piaget appear to be complementary. Any intention to pursue cognitive developmental research in geography, whilst learning from previous research applications and observations made in other disciplines, needs to give serious consideration to the potential contributions offered by different theorists. Next to Piaget, the most widely adopted viewpoint is that presented by Gagné. Possible contributions of Gagné's theory will raise the question of a dual theoretical basis (Piaget and Gagné) being adopted in concept research in geography.

3. The theory of Gagné

The second issue raised by Feldman (1971) involving stages of development in thinking processes has been dealt with above in relation to Piagetian theory. It remains to deal with the final issue in concept formation - that of the organisation of the conceptual system or hierarchy - on which Gagné offers a comprehensive view.

Gagné suggests that for a particular concept to be understood, the individual needs to possess the necessary prerequisite concepts. Gagné (1962), in his first study which later formed a base for much hierarchy research (White, 1973), suggests a method of identifying prerequisite concepts. The question is asked about a concept: What would the individual need to understand before he could attain adequate understanding of this concept? The same question is then applied to each of the prerequisite concepts, building a hierarchy of the concepts. Such a hierarchical ordering of concepts expresses relationships between concepts, constitutes the subject matter's concept structure, and is Gagné's main tenet (Anderson, 1972). On the basis of Gagné's postulated hierarchical relationship between concepts, a procedure for investigation of concept learning has been established. A concept is selected, and a proposed hierarchy is constructed by Gagné's method. The hierarchical relationships are then tested for validity empirically. Questions directed at testing concept understanding are constructed and administered on selected concepts in the hierarchy. The null hypothesis (that the postulated hierarchy is not valid) can be rejected if the individual cannot understand a higher level concept without understanding all the lower level concepts.

Illustrating the principle involved, Gagné proposed a hierarchical plan for curriculum design, beginning with concrete learning and basic concepts which facilitated the acquisition of more complex, abstract learning and concepts. The suggestion is that an education programme based on Gagné's plan will ensure with a high degree of probability that a student who began with the basic concepts could work through the hierarchy to an understanding of the complex concepts. Successful implementation of Gagné's method with major concepts within a discipline would work towards producing a master hierarchy for the subject matter. Within any field, old concepts are often being adjusted with a change or increase in the number of meanings, and new concepts are being introduced. The actual structure of a master hierarchy could not remain static, but would need to be continually modified and checked for validation. An example of a concept change in geography is the concept of space which has recently been given a number of different meanings (Harvey, 1969; Sack, 1972) and qualifies as a noun coupled with an increasingly varied selection of adjectives, e.g. physical space, social space, plastic space, race space. The concept of space is given detailed consideration in the discussion on the use of the concept of space in geography.

Examination of concepts and relationships between concepts in the form of a hierarchy facilitates a holistic view of subject matter and concept development. Hierarchies also assist discussions on content of courses and curricula design. Despite the valuable implications, hierarchical research has largely been restricted to the mathematics and science disciplines, and at times with inconclusive results (White, 1973). There are limitations associated with hierarchical research which will be discussed later in this chapter. Nevertheless, White (1972) observed that as a result of little concept research in geography, formal courses in geography tend not to be based on any hierarchy or sequence of concepts. In a review of British textbooks, Milburn (1972) found no rationale for the order in which concepts were introduced and in many cases no definitions were given of concepts and terms used. On the other hand much research in concept hierarchies has been done in physics. A few of the more recent studies will be outlined in the following chapter, illustrating the applications and some of the implications of Gagnéan research.

C. OVERVIEW

There has been a concentration on concept formation in this chapter. Feldman's (1971) suggested basic issues pertaining to concept formation provided the framework within which the theories of Piaget and Gagné have been outlined. Piaget's concern with a stage-developmental viewpoint is an attempt to make the implicit explicit. The students' concept structure and conceptual abilities become more explicit as their level of cognitive development is understood. Gagné on the other hand, is concerned with the concept structure of the discipline. The application of the two theories, although utilising the present knowledge of the concept formation process, contributes to the understanding of concept formation - a process as yet not fully understood. The value of Piagetian and Gagnéan research in concept analysis is being increasingly realised, evidenced in a growing body of literature providing useful and relevant findings.

In the following chapter, some of the more recent literature and research will be critically reviewed and considered in terms of possible applications in concept analysis research in geography.

CHAPTER THREE

CONCEPT ANALYSIS

Concept analysis examines how particular concepts are formed and attained by individuals (Feldman, 1971), and assists in the philosophical examination of the principles of fundamental concepts in a discipline (Nygren, 1972). Both the theories of Piaget and Gagné have major contributions to make in the field of concept analysis. A general survey of research in the context of secondary and tertiary education indicates that applications of Piaget's and Gagné's theories in concept analysis are largely limited to the exact sciences. This chapter is a critical review of recent concept research experience particularly in physics and chemistry at secondary and tertiary levels. Table 2 provides an outline of the structure of the chapter. The review of articles will be divided into three sections (A, B and C) according to the theoretical basis of each study: these are respectively, Piaget, Gagné, and integrations of both Piaget and Gagné's theories. This will be followed by (D) a summary of cautionary notes on the application of the theories in concept analysis. Finally, in the overview (E), the importance of concept analysis will be discussed in the light of the literature survey, with a view to concept research in geography.

A. Piagetian research	B. Gagnéan research
Division according to studies concerning:-	Division according to studies concerning:-
1) problems in learning - misconceptions and misunderstandings	1) concept hierarchies within disciplines
2) abilities of students to use concrete and formal thought	2) students' perception of hierarchical relationships between concepts
3) the relationship between cognitive ability and discipline content	
4) encouraging transition of thought from concrete to formal	
C. Joint Piagetian and Gagnéan research base	
D. Cautionary notes	
E. Overview and a possible theoretical base for concept analysis in geography	

Table 2. Framework for discussion on concept analysis

A. PIAGETIAN RESEARCH BASE

One of the most common justifications for the application of Piaget's theory in concept research is Piaget's underlying contention that education will only be effective when it is designed in accordance with the students' level of development. The content of articles on Piagetian research in concept analysis may be divided roughly into four areas:-

1. Problems associated with learning.
2. Abilities of students to use concrete and/or formal thought.
3. The relationship between cognitive ability and discipline content.
4. Encouraging the transition from concrete to formal thinking.

It needs to be stated at the outset, however, that the divisions are essentially artificial, useful only as a guide since many studies fall into more than one category. The four areas will be discussed in terms of examples of research in each of the areas, the first being discussed is that of misconceptions and misunderstandings.

1. Problems in learning - misconceptions and misunderstandings

If teaching is to be effective, knowledge of the students' conceptual abilities and previous knowledge is essential (Za'rour, 1975). 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 textbooks and teacher-instruction and even misconceptions held by teachers (Warren, 1976; Helm, 1978).

The four sources of learning problems may form the origins of resultant misconceptions or misunderstandings. For effective teaching then, it is important to be aware of possible misconceptions or misunderstandings, and to be able to trace their origins. The following is a review of four studies which have as their main aim effective teaching. However the difference between misconceptions and misunderstandings needs to be established at the outset.

Although the two terms are used interchangeably in much of the literature, misconceptions will hereafter refer to 'erroneous notions' which are held by groups of individuals (Za'rour, 1975). Misunderstandings will refer to erroneous notions which are neither commonly held nor identical amongst individuals. No attempt has been made to establish the point at which a misunderstanding occurs frequently enough to be termed common and therefore a misconception due to the exploratory nature of most concept research. The distinction is important however, in determining whether studies are referring to individual isolated problems, or more widely held common mistakes.

One of the major difficulties encountered in studies attempting to identify misconceptions (Doran, 1972) is the problem of devising a misconception scheme in the absence of a theory of misconception formation. That the absence of theory was still the case in 1978 was indicated by Helm (1978). Misconception studies aim to reveal more of the factors contributing to misconceptions by means of examination of misconception schemes and test techniques. One of the earlier misconception studies of science concepts was that conducted by Doran (1972) which first reviews the different approaches in constructing types of questionnaires as test-instruments, before going on to test American students on eight misconceptions. (The advantages and disadvantages of questionnaire types will be discussed in a later chapter on the questionnaire construction for the application of a concept analysis in geography.) The importance of Doran's (1972) study not only lies in the indication of a positive relationship between performance on the test, and age and school grade level of a student. Importance lies also in Doran's (1972) test approach, which recommends the testing of predetermined misconceptions, derived from literature, or from acquaintance with typical misunderstanding exhibited by students. The adoption of such an approach may be useful, but it needs to be ensured that the distractors offered would, as far as possible, enable the refuting of the supposed misconception or the revelation of previously unidentified misconceptions of the concept being tested. Helm (1978) in a misconception study of South African university students adopted an approach similar to that of Doran (1972). However, the use of a pilot sample testing the distractors offered, may have overcome the limitation mentioned. Za'rour (1975) classified misunderstandings as misconceptions if the choice of a distractor in the open-ended multiple choice test was selected by a percentage of students larger than the expected chance score. Adoption of Za'rour's (1975) criterion could be misused if distractors are not chosen carefully, and could merely ensure proof of the suspected. Should these limitations be overcome, the test instrument would then not only check the conceptions of those to whom the test was administered, but also would check the teacher's perception of prevalent misconceptions. Both are important since, as Za'rour (1975) emphasised, there is a need for students' misunderstandings to be able to be analysed, and regarded as valuable information.

Helm (1978) has found school teachers to have misconceptions about some of the concepts they teach and Warren (1976) refers to the inaccuracy and inadequacy of text book explanations. The origin of the teachers' misconceptions is not clear, but may be reinforced by misconceptions in textbooks. An associated problem is the use of pseudo-examples to teach a concept, transcribing an abstract concept into a concrete situation. To transcribe from abstract to concrete may facilitate the understanding of a difficult concept, but it must be realised by the students of the problem that an accurate conception is an abstract conception. It is necessary to ask at this point if the students are capable of abstract conception.

Although not all misconception studies employ a Piagetian framework explicitly, the studies may be seen as developments of initial misconception studies conducted by Piaget (1930). As conception is not divorced from cognitive ability, cognitive development theories would appear to contribute toward understanding misconceptions. Knowledge of the students' conceptual abilities and cognitive development would be essential in order to understand aspects of students' learning problems. The question of cognitive abilities of students is thus introduced.

2. Abilities of students to use concrete and formal thought

Studies attempting to identify the ability to think in a formal or concrete way, make reference to the level of cognitive development. Should the cognitive competence of the sample of students be established, conceptual and hence cognitive demands can be adjusted accordingly along with instruction techniques. Brady(1970) stresses the importance of awareness by teachers of the students' cognitive level, but further makes the point that this awareness is not easy to achieve. The category of studies under discussion consists of contributions working towards achievement of cognitive awareness through the application of Piaget's theory.

Although Piaget suggests that formal thinking begins at approximately twelve years of age (Table 1), most physicist researchers in education, by whom much developmental research has been conducted, have found that up to fifty percent of university students are not formal thinkers (e.g. McKinnon and Renner, 1971; Griffiths, 1977; Arons, 1976). Many concepts introduced at university level physics tend to require some degree of formal thinking. It would appear then that there is a discrepancy between the students' cognitive ability and the abilities required to understand many physics concepts. Tests for distinguishing formal from concrete thinkers have been designed by Rowell and Hoffman (1975), Lawson and Blake (1976), Brown, Fournier and Moyer (1977), and Lawson (1978) amongst others. The studies done by the mentioned authors were selected for discussion as demonstrating the research developments over time. The four studies will be outlined and discussed in terms of problem areas and contributions to concept analysis research.

Rowell and Hoffman (1975) attempted to translate two Piagetian standard tasks into forms suitable for administration to a number of students simultaneously - i.e. a group-test. Rowell and Hoffman's (1975) study points to one of the more obvious limitations of Piaget's experimental design: the reliance upon interviews on a one-to-one basis. Such design, called the clinical approach, involves a great amount of time, and there are difficulties involved in replicating interview situations if the research is to involve a large sample of students. Australian students from two classes in each of the first four years of a high school formed the sample. The results were analysed in terms of evidence of different levels of thinking, thus allowing the researchers to classify the students accordingly. The tasks, one in physics and one in chemistry, were chosen as having similar structure and hence cognitive demand, but involved different subject matter. The task choice was designed to test the hypothesis that a level of thinking ability demonstrated in one subject "...tends to be demonstrated with problems possessing a similar structure in another subject matter" (Rowell and Hoffman, 1975, p.158). Two comments on the study may be of relevance. Rowell and Hoffman state that those students who exhibited in their responses characteristics of transition between Piaget's stages, were classified as belonging to the lower of the two stages. Such a decision presupposes that to belong to a stage is more important than to be in transition between stages. The authors defend their decision on the basis that any teaching material to be administered to the pupil as a result of the test should match the lower rather than the upper stage. Such a defence is questionable, since the period of time during which pupils may exhibit transitional characteristics can vary greatly, and material which would encourage and stimulate development of thinking toward the upper level may be of more use than material which the student has largely understood. Without taking the idea of stage too far, which is a danger later discussed, the transition between stages could be given the status of a stage itself since it has characteristics of its own, and is part of the spectrum of cognitive development. Further discussion on encouraging growth in cognitive abilities will arise in the following section.

The second comment pertains to Rowell and Hoffman's hypothesis. Their results were not definitive. It has been shown (Fuller, Karplus, and Lawson, 1977) that one of the difficulties associated with attempting to classify students as either concrete or formal thinkers, is that students may exhibit formal thinking in one area and only concrete in another area but on a similar task. Further, the authors tabulate responses according to percentages of students classified in the different stages separately for the two tasks, and conclusions were drawn on this basis. There appears no evidence of analysis on an individual basis. For example, establishing whether the particular students who exhibited concrete thinking on the one task, were the students who performed concretely on the other task.

Rowell and Hoffman (1975) however, do offer contributions in the area of:-

a) Stressing the need for awareness of students' cognitive abilities so that appropriate material or concepts may be introduced to the student at the most beneficial time.

b) Providing an initial attempt to construct a reliable and valid group-test of cognitive ability.

A number of issues raised in the Australian study have been taken up subsequently in later research, exemplified by the studies in the following discussion.

A group of sixty eight American high school students served as a sample for Lawson and Blake's (1976) study. Lawson and Blake (1976) were concerned with identifying concrete and formal thinkers, and with the tests which classified the abilities. Three tests were used. A set of Piagetian standard tasks were administered by means of the clinical approach. A biology pencil-and-paper examination and an examination of non-science content were administered in a classroom situation. The use of contingency tables to compare responses on the tests, largely overcomes the problem of analysis by aggregation as raised in the discussion of Rowell and Hoffman's study. The examination of the three tests was in order to establish whether Piagetian tasks were 'content-free' as implied by Piaget, and hence test cognitive ability and not content knowledge. 'Content-free' refers to the fact that although the task may employ subject matter, no prerequisite knowledge of the subject matter is presumed. Such an examination is an extension of the question posed by Rowell and Hoffman (1975) as to cognitive ability exhibited on similarly structured Piagetian tasks but involving different subject matter. The value of Lawson and Blake's (1976) study lies in the finding that Piagetian tasks are largely content-free. The implication of the finding is that the large number of adolescents and adults shown by Piagetian tests to be operating at the concrete level cannot be explained by a content bias.

As mentioned briefly in the outline of Piaget's theory, a number of factors are purported to influence operational ability, such as culture, experience, and age. The research by Brown, Fournier and Moyer (1977) attempts to ascertain whether culture can explain poor performance on tests designed to reveal abilities in operational thinking. Results suggest that the Mexican-Americans tested scored significantly lower than the Anglo-Americans tested. The study is difficult to assess since little information is given on the structure and administration of the paper-and-pencil test. Although there are many studies testing the effect different factors have on cognitive ability, (e.g. Elkind, 1962; Graves, 1975; Za'rour, 1975), a research need at present lies in further development of reliable testing methods.

Lawson (1978) examines at depth the possibility of a test format which would include the advantages of the clinical approach, and overcome the demand in paper-and-pencil techniques on reading and writing abilities, whilst still being a group-test. The format adopted included a demonstration using apparatus as used in the clinical approach, but performed before the group to be tested. The demonstration was used to pose a question, and the students responded in a booklet by checking the box next to the best answer out of the alternatives offered beneath the question which was also given in writing. The respondents were then asked to give a written explanation for their answer. The test was administered to 513 students from a variety of high schools and school grades. An important research development is Lawson's (1978) treatment of the transition between concrete and formal thinking as having equal status as the stages of concrete and formal. The contribution made by Lawson (1978) is an important one, providing a format which, as Lawson (1978) states, tests the parameters measured by the clinical approach in a group-test, which was found to have a high degree of validity and reliability.

A review of research into misunderstandings and misconceptions of the subject matter has been followed by a brief survey of research dealing with the cognitive levels of students. The two research areas will be drawn together in the following discussion of studies which examine specifically the relationship between cognitive ability and subject content.

3. The relationship between cognitive ability and discipline content

Since most science concepts introduced at first year university level are formal (Cantu and Herron, 1978), and since recent Piagetian research has indicated that up to fifty percent of university students are not formal thinkers (e.g. McKinnon and Renner, 1971), a question arises as to the compatibility of pre-formal cognitive ability of students and formal conceptual demands in science content. There are two possible research areas within the question raised:-

a) The relation between cognitive level and ability to understand the discipline's content.

b) The use of instructional techniques and order of content to promote cognitive growth.

The first research area will be discussed below, the second area being relevant to the fourth section following, on encouraging the transition of concrete to formal thought.

Kolodiy (1977) compared college students' performance on Piagetian tasks administered by the clinical approach, and the students' performance on tests set by the college on the discipline. The size of Kolodiy's sample of twenty five was explained as due to the time and cost of the clinical approach. Although results from the research cannot be conclusive because of the sample size, two main conclusions were drawn. On the one hand, the majority of students demonstrated pre-formal thinking on the Piagetian tasks. on the other hand, results indicated that formal thinking was not a criterion for college 'success'. Despite the small sample, Kolodiy's (1977) results seem to support Schwebel's (1972) statement that when pre-formal students are confronted with formal subject content, the students will tend to resort to recall. The student is then marked in terms of recall ability and not thinking ability.

A similar study by Barnes (1977) tested a far larger sample of 338 American students. Unlike Kolodiy's (1977) study, Barnes (1977) administered a Piagetian test in the form of a questionnaire requiring written responses. With regard to the more elementary courses in the engineering faculty tested, results tend to suggest that students can not only pass but get a high grade, without the ability to think formally as indicated in the Piagetian tests. The findings by Schwebel (1972), Barnes (1977) and Kolodiy (1977) do not render cognitive studies irrelevant for university student performance, but rather stress:-

a) The need to review what the college or university examinations aim to test.

b) The importance of further refining tests of cognitive ability.

The two points are vital in investigating improvements in the effectiveness of educational techniques. On a smaller scale, Barnes' (1977) study reveals a number of points worthy of noting.

Barnes (1977) suggests that written questionnaires and oral interviews as forms of testing Piagetian-based cognitive abilities "...yield about the same results" (Barnes, 1977, p.845). Such a statement, although discussed in greater detail in the questionnaire construction in a later chapter, has a number of research implications, some of which have been mentioned previously under section 2 of this chapter. A few of the implications include:-

a) The different testing methods make dissimilar demands on reading and writing ability.

b) The questionnaire is less flexible, not allowing for ambiguities in questions to be clarified.

c) Different types of questions asked can elicit differing forms of answers.

Indeed, the importance of the choice of testing method is emphasised by Osborne and Gilbert (1979). In an attempt to overcome as many of the disadvantages as possible in testing techniques, Osborne and Gilbert (1979) designed a testing method referred to as 'Interviews About Instances'. This and other methods will be discussed in more detail in a later chapter. The point being made is that test-instruments are crucial in determining the type of data collected, and attempts are still being made to construct tests with a high degree of validity and reliability.

A second important point raised by Barnes' (1977) study is the variations in responses, where students may demonstrate formal thinking on one task, and not on another. The comments made previously regarding stages are relevant here. Good (1977) refers to the 'myth of stages', suggesting that since development is continuous, the division into stages is artificial and useful only for communication purposes. In the light of Barnes' (1977) study, inconsistency exhibited in levels of performance may be attributed to the suggestion that cognitive growth is not at all times even. Advances may be made in one area and not in another. Sayre and Ball (1975) suggest that all teachers need to become aware of and develop an understanding of Piagetian theory. Teachers would then be able to provide appropriate content, within the bounds of the curriculum, and appropriate instructional techniques. Being able to identify areas where cognitive advances have not been made, through the content of the particular discipline, the teacher could encourage growth of thinking ability. The final section on Piagetian studies will consider in particular the encouragement of formal thinking.

4. Encouraging the transition of thought from concrete to formal

The use of instructional techniques and content order to promote cognitive growth is a rapidly growing research field. Since the realisation that a large proportion of students in tertiary education are pre-formal thinkers (e.g. McKinnon and Renner, 1971; Arons, 1976; Griffiths, 1977), much research has centred on methods designed to promote intellectual growth. Examples of some of the studies concerned with encouraging formal thinking will be discussed, and will be followed by a summary of Cautionary Notes on Piaget.

On administering Piagetian-based texts, McKinnon and Renner (1971) found the majority of a population of U.S. college freshmen to be pre-formal in concept ability. The administration of a one-semester course in science based on an inquiry approach caused what McKinnon and Renner (1971) termed significant cognitive growth in the groups. Blake and Nordland (1978) stress the importance of McKinnon and Renner's (1971) findings:-

a) They indicate the possibility of identifying concept abilities of students.

b) The findings support Driver and Easley's (1978) contention that cognitive demands may be adjusted to student competences in such a way as to promote cognitive growth.

The use of Piaget's theory as a basis to indicate concept abilities of students and to guide subsequent instructional strategies is being investigated by Arons (1976); Lawson and Wollman (1976); and Cantu and Herron (1978). The strategies are intended to lessen the likelihood of reinforcement of misconceptions due to an imbalance in cognitive ability and demand; and to facilitate conceptual ability. The latter facilitation is important, since according to Lawson and Wollman (1976), cognitive maturation only indicates the potential abilities and such abilities need to be realised. There would seem then, to be a responsibility on behalf of the teacher which requires an ability to implement knowledge of cognitive theory in the classroom situation.

Lawson and Renner (1975) conclude that formal thought should be the focal point of every teacher, the aim of the teacher being to teach the ability to think. Such knowledge, however, is not easy to gain or implement. Herron (1976), in commenting on Sayre and Ball's (1975) suggestion that teachers be trained to encourage the transition between concrete and formal, states that although the encouragement is extremely important little is as yet known as to how to promote the transition. Herron (1976) further states that much work is yet to be done before strong demands on the teachers can be made.

The section thus far has attempted to stress the interdependence of cognitive development and concept abilities in concept analysis studies. The four areas of concept research are broad, and are of importance in working towards clarifying terms used, facilitating communication, and increasing the effectiveness in teaching students to think. In the light of Piagetian theory and the literature cited, it remains to summarise briefly some of the more important cautionary notes which need to be taken into account in any consideration of concept analysis in a discipline. This will be undertaken in conjunction with an outline of limitations of Gagnéan research following the discussion on Gagnéan and joint Piagetian-Gagnéan research bases.

B. GAGNÉAN RESEARCH

Following Gagné's preliminary studies (Gagné and Paradise, 1961; Gagné, 1962; Gagné and Bassler, 1963) where Gagné's hierarchical theory was formulated, hierarchical research by other authors has adopted Gagné's experimental design. Reference below to recent research into postulated and investigated hierarchies will reveal two important points. Firstly, the foundation Gagné has laid for hierarchy research will become apparent. Secondly, the important implications of hierarchical analysis being relevant to any discipline issues a challenge to all who are involved in learning and teaching programs. Gagnéan research will be discussed under two headings, each dealing with different research areas: concept hierarchies, and perceived hierarchical relationships.

1. Concept hierarchies within disciplines

The majority of hierarchy studies have been concerned with the exact sciences. A study by Howe (1974) will be outlined in detail as it examines a concept hierarchy within the discipline of physics. Howe's (1974) study also demonstrates the application of hierarchy research, and some implications of Gagné's methodology. Brief reference will be made to other studies which exemplify certain relevant points.

In examining the acquisition and growth of an important concept in physics - conservation of liquid - Howe (1974) focussed on a proposition made by Gagné. Gagné proposed that what is lacking when physics students are not able to perform conservation tasks, and hence exhibit understanding of the concept, is the understanding of prerequisite concepts, rather than the ability to perform set tasks. To validate the concept hierarchy proposed by Howe (1974), understanding of the higher level concepts should be inadequate without the understanding of lower level concepts. Alternatively, a hierarchy may be considered valid if acquisition of lower concepts allows acquisition of higher level concepts. On administering questions to test concept understanding to twenty American pupils aged seven to ten years, Howe (1974) found that in some cases higher level concepts in the hierarchy were adequately understood by those who did not understand lower concepts. Although Howe's (1974) data did not indicate validity of the proposed hierarchy, the study nevertheless illustrates the implications of Gagné's methodology, raising certain issues. The first issue is the difficulty in defining what constitutes an adequate understanding or mastery of a concept - a question faced by all involved in teaching. Such an issue may only be resolved independently for each concept tested. The uniqueness of each concept prevents formulation of any rule in this regard. A second issue raised is the difficulty entailed in constructing a valid hierarchy, and it is often necessary to proceed by trial and error (Preece, 1976). One further question involves whether or not the tasks set to test concept understanding actually fulfill that purpose. The three issues mentioned are not peculiar to Howe's (1974) study but are raised in much of concept research.

Shavelson (1974) emphasises the necessity for knowledge of concept hierarchy structure in the sciences to aid retention and problem-solving abilities. However, the need is noted by Shavelson (1974) for further research into the actual acquisition of concepts and their organisation in memory since so little is known about the role played by memory in hierarchical understanding. Mannino et al (1973) examined the commonly accepted order of teaching of fundamental concepts related to electrostatics. Ninety students in their last year of high school were submitted a questionnaire which tested the students' knowledge and level of understanding of electrostatics concepts. Mannino et al (1973) found that concepts commonly accepted as prerequisite (e.g. concepts of potential) to that of a supposedly higher concept (e.g. concept of energy), were in contradiction with the levels of difficulty of the concepts and the students' responses. As a result of the study, Mannino et al (1973) suggested alternative teaching strategies. From the hierarchies discovered in their study, one of the suggestions was to teach the concepts of potential and energy in the reverse order to that commonly accepted. Conclusions such as those of Mannino et al (1973) and Shavelson (1974) demand a response from those involved in teaching to justify the order in which they teach concepts.

Methods of representation of concept hierarchies are being explored, and Johnson et al (1971) investigated a representation method using six concepts of mechanics for university physics students. Johnson et al (1971) constructed the hierarchy from the simplest to the more complex, and represented the concepts in a model. The similarity and relatedness of concepts was indicated in the model by their proximity in a three dimensional semantic space. The hierarchy was not only tested for validity but was found to serve as a useful heuristic device in teaching the relationships between concepts. Riban (1971) in examining students' deficiency in mathematics, also found a hierarchical model to be of heuristic value and to provide a basis from which to view subject matter structure. Students themselves, however, have a perception of subject matter hierarchies and they may or may not agree with researchers' postulated hierarchies.

2. Students' perception of hierarchical relationships between concepts

It is important that the students' perception of the hierarchical structure of subject content is not in conflict with the relational structure of concepts that constitutes the subject. Both structures are difficult to identify, but research in both areas is necessary for effective learning and teaching. The way in which an individual perceives relations between concepts will affect and be effected by the way he proceeds to solve a problem or process information. One of the earlier studies on perceived relations between concepts was conducted by Kass (1971) and will be outlined below, followed by a later study by Toews (1976). Other studies which bring to the fore aspects not dealt with by Kass (1971) and Toews (1976) will be cited before drawing together the motivations for studies of perceived relations between concepts.

Kass (1971) investigated a method of representing the structure of perceived relations revealed by students. Twenty mechanics physics concepts were selected from a grade twelve text used by the students participating in the study. A multiple choice test was administered to 353 grade twelve Canadian physics students on completion of the mechanics course. The students were required to indicate the degree of difficulty of the concepts. Kass surmised that since all the concepts selected were related, the difficulty of one concept compared with another would be an indication of the relative positions of the concepts in a hierarchy. Kass termed the relative positions as proximity, and proceeded to explore the possibilities of representing the hierarchical proximity of concepts in terms of a multi-dimensional Euclidean space. If such a representation were viable, the hierarchy could be subjected to mathematical precision. On the empirical data collected, Kass (1971) constructed a hierarchy based on averages of students' perceptions of difficulty of concepts and hence their proximity. Kass (1971) concluded that the exercise was useful in that it revealed how the students' perceived concepts were associated with each other. Although Kass does not mention it explicitly, such an investigation would be helpful in identifying perceived misconceptions students may have, and in tracing possible causes for the misconception, along the lines of the association between concepts given by the students. The research procedure is, however, elaborate and time consuming, and not easily conducted by teachers for their own classes. A procedure more readily adaptable for frequent use amongst teachers was initiated by Toews (1976).

The aim of Toews' study was to compare students perceived hierarchical structure of selected concepts with the hierarchical structure defined in the science curriculum. Forty-seven eighth grade North American students were selected, all of whom had experienced the relevant concepts as set out in the curriculum. The students were exposed to two tests. The first required each student to sort and group statements describing the concepts into categories of their own choosing according to the students' perception of the relations between the concepts. The second test functioned as a check for consistency in the students' responses - the accuracy of the grouped associations of the first test not contradicting the students' concept adequacy displayed in the mastery test. To process the data, a hierarchical cluster analysis was applied to the categories and hierarchical relationships between the categories. Toews (1976) concluded that although the perceived hierarchical structures conformed to that of the curriculum, the degree of conformity was not strong. One of the most important statements made by Toews (1976) as a result of the study is directed toward the teacher. Toews (1976) states that if the student is to form coherent and stable perceived concept structures, the teacher must be able to maintain a perspective of the concept structure of the total curriculum. Such a perspective facilitates the communication of how the individual concepts taught fit into the course as a whole. The question to consider at this point is: In what way do the students' perceived concept structures effect learning and teaching?

To the question just posed, Johnson et al (1971) contribute an answer in the area of learning. Johnson et al (1971) tested forty nine male physics majors at the University of Minnesota. The test was designed to reveal which concepts were evoked in the students' mind when the students were presented with concepts given by the instructor. The similarity and relatedness of concepts were represented in a hierarchy by their proximity in a three-dimensional semantic space. Johnson et al (1971) postulated that particular concepts are evoked in a student's mind when encountering other concepts, because one concept can be explained in terms of other concepts, and are therefore associated. The study by Johnson et al (1971) presents a technique for discovering students' correct and incorrect concept associations. The work could be extended by using the technique to reveal misconceptions as indicated by incorrect concept associations, since, according to Preece (1976) concept associations are the perceived concept structures. However, Johnson's (1971) study indicates that the ability of a student to increase his understanding of a concept is bound not only by the accuracy of his perceived concept relations but also his ability to let go of past associations to make new associations possible.

Further ways in which students' perceived concept structures affect learning were given attention by Shavelson (1974). Shavelson (1974) examined techniques for discovering and representing perceived structures, and comparing these with the subject-matter structure as given in texts and the curriculum. Problem solving, learning,and retention are facilitated if the perceived structure is close to being identical to the subject-matter structure. Shavelson (1974) also notes that the perceived structure needs to be accurate, since knowledge of the structure effects the understanding of the subject as a whole.

The ways in which learning is affected by perceived concept structures, will in turn affect the required approach of the teacher. However the teacher needs to be aware of two points. Firstly, the teacher needs to know the differences that exist between his own perceived structures and those of the students. Secondly, the teacher needs to attempt to understand why the differences exist for each class and for each individual. Such a task is not easy, as it covers the wide field of perception, conception and cognitive growth. It is here that cognitive theories such as that by Piaget can complement theories of concept structure. The case for a joint Piagetian and Gagnéan research base will now be argued.

C. JOINT PIAGETIAN AND GAGNÉAN RESEARCH BASE

In summary, the theories of Piaget and Gagné may be in apparent contradiction: the former suggesting that the individual can only assimilate and understand concepts which match his conceptual ability; the latter implying that as long as the concepts are taught in the correct order, understanding of the upper level of concept in the hierarchy is probable. However, such a summary is also a simplification. Although each stands in its own right, having areas of justifiable utility and application, the two may be coupled for more comprehensive analysis. Indeed, in the area of curriculum development and learning theory, such a coupling of the theories would appear imperative. Research in that area has revealed that subject matter structure cannot be isolated from consideration of the students' cognitive development (Wallace, 1976).

On the one hand, Phillips (1971) refers to the results of curriculum development based on Piaget's theory alone as disappointing. Phillips (1971) based his research on the realisation that a curriculum cannot be derived from Piaget theory alone, without exploring the subject matter structure. On the other hand, Robertson and Richardson (1972) view concept structure research as laudable, but emphasise the need to match the introduction of concepts in the hierarchies to the students' Piagetian stage of development. Although not a common procedure, a dual theoretical base was employed by Robertson and Richardson (1972) who investigated the generally accepted structure of physics concepts as exemplified in texts. The hierarchical concept structure was analysed in the light of Piaget's cognitive approach. A final example of research adopting a dual theoretical approach is a study by Benefield and Capie (1976). Piaget's cognitive stages were recognised as invariant in order and therefore hierarchical, but that the stages themselves are very broad. Within each stage are a set of tasks or sub-operations, for which Piaget did not give a "...statistically valid description of the order or dependency relationships among these operations" (Benefield and Capie, 1976, p.194). Benefield and Capie (1976) aimed to discover something of the order of the sub-operations. The method used to identify order was derived from Gagné's theory, asking the question of each task: what would the individual have to understand before he could master the task? The resultant postulated hierarchy was then tested for validity by determining the order of acquisition of the tasks by a sample of students. So Benefield and Capie (1976) used a method adopted from Gagné to investigate weak areas in the theory of Piaget. Both theories have weak areas which will be discussed in the following section. What is becoming clear in this section is the complementarity of the two theories. Used together in a research project, the theories enable exploration and examination of concept structures and subsequent teaching strategies in the context of students' cognitive abilities.

A dual Piagetian-Gagnéan approach, then, allows for a more comprehensive analysis of concept learning and teaching than a singular Piagetian- or Gagnéan-based study. Complementary as they are, there remain limitations encountered in concept analysis associated with the theories of Piaget and Gagné, as well as with the nature of concept research as developed to date. An awareness of the limitations is fundamental, indicating research areas which need improvement, and influencing the strength with which conclusions can be drawn from a study.

There are few studies which adopt the dual basis of Piaget and Gagné. Yet in view of the research to date - both dual-based studies, as well as single-based studies where the researchers have indicated the limitations - it can be reasonably argued that it is empirically well-established that for a full understanding of a discipline's structure and for effective learning to occur, there is the need for hierarchical ordering of concepts (Gagné, 1970) with an awareness of students' cognitive abilities (Piaget, 1956).

It is suggested that a dual theoretical basis incorporating the theories of Gagné and Piaget be critically examined in view of applying the basis in geographical concept research. One of the central purposes in the study proposed is to review critically Piaget's and Gagné's theories. Since the study is largely exploratory in geography, a problem-centred approach will be adopted, and the proposed dual basis is used in an actual case study examination of concepts of space. In adopting the dual basis, the main tenents of both Piaget's and Gagné's theories are accepted. Namely, for Piaget (Kolodiy, 1977): cognitive growth proceeds in certain stages; these stages occur in the same order for all individuals; and each stage is characterised by the ability to perform certain mental functions. The main tenet of Gagné (1970) is that all concepts are related to other concepts being prerequisite for the understanding of higher level concepts. It would appear then, that there is a case for drawing on the complementary aspects of Gagné's and Piaget's theories in concept research. As previously indicated, both theories remain with weaknesses, and there are limitations in concept research. It is worth making a précis of these weak areas and limitations and taking precaution in research methodology and the strength with which conclusions are drawn.

D. CAUTIONARY NOTES

Thus far Piaget's and Gagné's theories have been considered in the context of concept analysis. Many problems have been encountered in concept research, and an indication of this is the lack of any single widely accepted methodological procedure (Helm, 1978). Such a lack is the first and major problem. Other areas where problems exist will be outlined below under the three subsections of Piaget, Gagné, and concept research.

1. Cautionary notes on Piagetian theory

There are many criticisms and limitations of the thinking which grew out of Piaget's work, known as the Genevan school. The use of stages is central to Piaget's work, and as indicated in the previous discussion on Piaget's theory, the ages at which these stages are reached vary considerably between population groups. Such variation is due to differences in maturation, previous experience, and cultural milieu (Feldman, 1971). Indeed, Good (1977) refers to the 'myth of stages' in stressing the point also made by others (Rietman, 1965; Flavell, 1972; Neisser, 1976) that development is a continuous process, and the term 'stage' should be used for ease of communication rather than as categories in search of stereotypes.
The contribution of the Genevan school to understanding the cognitive realm remains tentative in the area of transition between concrete and formal operations. In attempts to contribute understanding in this area, empirical studies have often revealed an inconsistency in what should be a fixed sequential growth in cognitive ability, which is in contradiction with the theory (Smedslund, 1966; Pinard and Laurendeau, 1969; Wallace, 1976). Such findings in part have been attributed to research based on interpretation of Piaget's developmental sequence as being more concerned with abilities exemplifying the particular stages, rather than with processes involved in transition between stages. There is not only lack of clarity of between-stage

processes, but also of the within-stage range of abilities (Benefield and Capie, 1976). Although Piaget postulated a number of sub-operations within the stages, investigations are continuing to work toward more information. Related to this problem is the finding that students may exhibit evidence of, for example, sub-operations of formal operational thinking in response to one task and not to another. Difficulty lies in isolating the reason for the inconsistency of conceptual ability exhibited. Of the many possibilities such as previous learning experience and misunderstanding, is that of the context. Piaget (1972) admits to error in a previous statement (Piaget and Inhelder, 1958) which suggested that formal operational thinking takes place independently of the context in which it is required. The change in understanding evidenced in Piaget's correction brings to the fore two points.

In the first instance such a change introduces a complication, since it is difficult to define contexts. In other words, of the surroundings and available information,what constitutes the context for a student? in the second instance, Piaget's correction indicates that aspects of the theory are still requiring refinement. In fact, further than that, conclusions from two studies claim that Piaget's theory of stages bares no relationship to students' performance on tasks. The position is taken instead that previous experience and individual student abilities dictate performance. These are only two studies against the relatively larger number of studies which support Piaget, but only continued research will determine the relative truths of the two positions.

The discussion has been on the limitations of Piaget's theory which are pertinent to concept analysis. There is no suggestion that the problems mentioned exhaust the problems encountered in all Piagetian research. As Wohlwill (1968) has indicated, Piaget's theory is being used in many research fields as a theoretical base whilst at the same time the theory is being tested and weak areas are being explored. The focus has been on areas of the theory requiring caution by the researcher. There is a final caution to note: that although Piagetian theory has many restrictions, total rejection of the theory is unfounded. The theory has served as a research base which on application has revealed areas previously unrecognised as requiring research. Many modifications and extensions of the original intentions of Piaget have been and are being made, including the use of Piaget in conjunction with other theories.

2. Cautionary notes on Gagnéan theory

Although researchers in concept hierarchies do not always acknowledge Gagné explicitly, Gagné's theory has not only instigated hierarchical research but has provided a research framework (Anderson, 1972). Hence the limitations discussed below in Gagnéan theory largely apply to hierarchical research in general. Since some limitations are unrelated to others, the notes will be expressed in point form.

a) Gagné indicates that hierarchical relatedness is necessary for the validation of a concept hierarchy. However, White (1974) warns that alone it is not a sufficient condition: "Because nearly everyone who can solve differential equations can spell 'cat', this does not show that spelling 'cat' is an essential prerequisite to learning differential equations" (White, 1974, p.63). Each concept has to be examined as to its being essential for the understanding of the next higher concept in the hierarchy. The problem of hierarchy construction is thus raised.

b) Particularly for previously unresearched concepts, and geography concepts would have to be included here, hierarchy construction often has to proceed by trial and error (Preece, 1976). This can be not only time consuming, but also misleading, since often the hierarchy initially can only be tested against students and texts, whose misunderstandings can give an inaccurate indication of the hierarchy's validity.

c) Techniques for validating hierarchies have been criticised heavily, exemplified by the dialogue between Hoffmann (1977) and White (1977), and is an area where much research remains to be done.

d) Hierarchy research is committed to a focus on invalid hierarchical connections. The reason for this focus is that hierarchy research has not yet developed beyond enabling confirmation or rejection of postulated connections, to the identification of those connections which are not considered (White, 1973). Also, present methods do not allow for the net to be thrown too wide to include the testing of all possible related concepts. The researcher has then to select a set of concepts to be tested immediately introducing a bias to the hierarchy.

e) It is essential to define each concept in the hierarchy accurately, since Linke (1975) and Gower et al (1977) discovered that different common definitions of concepts dictated differing hierarchical ordering of concepts. Although the importance of finding a universally agreed definition for concepts is obvious, it is a difficult and often arduous task to find an acceptable definition for exact and non-exact science concepts (White, 1973).

f) Few have rejected Gagné's theory on an empirical basis, but one study was that conducted by Merrill (1965). Merrill gave instructions to two groups of students. The one group had to master each step in the hierarchy before being able to move on to the next step in the hierarchy. The other group were not forced to master each step before attempting to master the terminal concept. Since the former group took longer to master the terminal concept than the latter group, Merrill (1965) doubted Gagné's theory. White (1973) finds Merrill's (1965) study unconvincing for a number of reasons - one being that the hierarchy was not validated. Nevertheless conclusions such as Merrill's highlight the point that Piaget's question of "How do we come to know?" (Driver and Easley, 1978, p.70) is far from answered; and still yet the question: How do we know? However, the questions are not limited to Gagné's theory, and applies to concept analysis generally.

3. Cautionary notes on concept analysis

Experience of researchers in concept analysis alerts prospective researchers in the field to a number of difficulties and limitations encountered. Problem areas which arise when the theories of Piaget, Gagné or both are used in concept analysis are briefly discussed below within the context of the possible application of the research to geography concepts.

a) Nedelsky (1965) has outlined the difficulty in defining the role played by intuition when trying to establish precisely the order in which empirical concepts are learned. For example, Karplus and Karplus (1970) raise the question as to the extent to which a vague intuitive awareness of prerequisite concepts is sufficient to enable higher concepts to be fully understood. Developing out of Karplus and Karplus' (1970) question, is the point that intuitive awareness itself is difficult to measure, and thus remains as yet an unresolved problem.

b) Riban (1971) suggests that misunderstanding of physics concepts often originate due to different meanings given to the terms in other disciplines. It is suggested that due to the interdisciplinary nature of geography a similar problem may be found. The origin of misunderstanding outside a single discipline makes within-discipline concept studies difficult in tracing the exact origin and in planning a remedial course.

c) Questions of what constitutes adequate understanding, concept mastery, and misconceptions, are difficult and can only be tentatively resolved for each concept.

d) As Driver and Easley note (1978) the majority of published research reports on concept research do not outline the instruction given to the students or the detail of the questionnaires or interviews administered. Such neglect generates the likelihood of repeated mistakes in future research and limits the extent to which research can build on the experiences of the past. The lack of detailed information may have contributed to the difficulty in developing a single widely accepted methodological procedure.

e) Although Piaget's work lends itself to longitudinal studies, few concept analyses observe the development of individuals over several years. Longitudinal studies would contribute to the bank of knowledge in concept analysis, but would not necessarily contribute to understanding the process of concept learning. This is largely due to the fact that concept studies are still of an exploratory nature, with techniques of data analysis and methods of conducting the study being explored.

f) The search for trends amongst students is essential for effective instruction and learning. However, conclusions drawn from the studies lose credibility if the perspective of the "...essential individuality of learning" (Driver and Easley, 1978, p.80) is not held in tension with a trend-perspective. It is hence necessary to be cautious about how the individual is regarded in relation to the revealed trends.

g) The search for trends in itself holds a number of problems:-

i) Amid the debate on the relative values there needs to be careful selection of interview and testing techniques appropriate to the aim of the study.

ii) It is often difficult to assess whether tasks set to test concept understanding actually fulfill that purpose.

iii) There is an inevitable subjective element in selection of concepts, wording and phrasing of questions, and partially in the categorisation of students' answers.
Further administrative detail will be discussed in a later chapter when a questionnaire administered to geography students is considered.

The limitations and problems discussed above indicate a few of the refinements needed, suggesting areas where caution needs to be exercised by researchers. At the same time, the outline of Piagetian and Gagnéan research signifies the relevance and value of concept research. The overview below will attempt to draw together the above sections in the argument for introducing concept analysis to selected geography concepts, and the adoption of a dual theoretical base for the research.

E. OVERVIEW AND A POSSIBLE THEORETICAL BASE FOR CONCEPT ANALYSIS IN GEOGRAPHY

The goals and values of concept analysis have been revealed in the previous chapter on concept formation, and in the discussion of examples of concept research. Four fundamental reasons for the urgency and vital concern for concept research are:-

1. With continued research, means of promoting the development of formal thought may be constructed.

2. The value of listening to the learner needs to be recognised to understand what the learner understands and misunderstands, and why.

3. It needs to be realised that the following are profitable tasks: examining course structure; establishing degrees of difficulty assumed about the concepts; researching the order in which concepts are introduced; and checking the teachers' perception of the learners' abilities.

4. Concept analysis assists in the philosophical examination of the principles of the important concepts in a discipline (Nygren, 1972). Such examination demands continual revision and clarification of concept structure and meaning and also checks ambiguity and inconsistency in use of the concept. Gilbert (1977) has noted that the rapid development of knowledge in physics has made education increasingly difficult, with old concepts continually

being redefined. Geography experiences similar difficulties, including the formation and extension of new concepts. The concepts of space in geography are an example here. However, concept analysis as it is presently understood, is not without flaws or difficulties. The possible contributions of concept research mentioned, in part depend on many problems being overcome.

Limitations encountered in the research pointed out problem areas in concept analysis in general and in both Piaget's and Gagné's theories. Despite the theories' restrictions mentioned, Lunzer (1976) makes an observation regarding Piaget's theory. Lunzer (1976) points out that the importance and relevance of Piaget's work is not that it remains unchallenged, but rather that such a theory opens up new areas of inquiry, while at the same time offering an interpretation of cognitive and conceptual phenomena previously seen as unrelated. Gagné's theory does not fall outside the boundaries of Lunzer's statement. Both theories contribute to revealing areas of research need, thus working towards more effective learning and teaching. One research need as a result of limitations is expressed by Lunzer (1976). Lunzer (1976) suggests that approchement needs to be found between the Genevan approach and that of recent behaviourists in cognitive research such as Bloom (1956), Carroll (1956) and Gagné (1966). In doing so, complementary, supplementary and substitutionary aspects may be explored as to their applicability to concept research in general.

On drawing together in summary the theories by Gagné and Piaget, complementarity can be found. For example, Gagné (1966) envisages a hierarchy constructed on previous knowledge - knowledge of prerequisite concepts enabling understanding of concepts higher in the hierarchy. A complementary aspect of the Piagetian hierarchy deals not so much with the knowledge necessary for understanding but with the cognitive processes required for the understanding of concepts at different levels in the hierarchy.

Any attempt at cognitive development research in geography, whilst learning from previous research applications and observation made in other disciplines, needs to give serious consideration to the potential contributions offered by the different theorists. It would appear then, that there is a case for drawing on a joint Piagetian-Gagnéan theory in concept analysis. It is suggested that a dual theoretical basis incorporating the theories of Piaget and Gagné can be adopted for concept research in geography. The proposed dual basis is used in an actual case study examination of concepts of space. Since the study is largely exploratory in geography, a problem-centred approach is employed. In adopting the dual basis, the main tenets of both Piaget's and Gagné's theories are accepted. In summary, for Piaget these are (Kolodiy, 1977):-

1. That cognitive growth proceeds in certain stages.
2. That these stages occur in the same order for all individuals.
3. That each stage is characterised by the ability to perform certain mental functions.

The main tenet of Gagné (1966) is that all concepts are related to other concepts in the form of a hierarchical network, understanding of subordinate concepts being prerequisite for the understanding of higher level concepts. The proposed dual theoretical base will be used in the actual case study examination of the concepts of space in geography.

Piaget's and Gagné's theories have been reviewed critically, adopting a problem-orientated approach to what is a new and growing area of research interest. The major issues in concept analysis have been referred to in consideration of the experience of other disciplines. The following study serves as an initial study of concept analysis in geography, again utilising a problem-centred approach, complying with the exploratory nature of the research as a whole.

CHAPTER FOUR

THE CASE STUDY - SELECTION OF CONCEPTS AND METHODOLOGY

Concept analysis in geography is at an early stage. By application to concepts in geography, this chapter explores concept analysis as a method for revealing problems in learning and teaching, and as a guide toward specific areas for improvement. As the study is exploratory in nature, detailed explanation of each step is essential. Hence it is a lengthy chapter, primarily focussing on the efficacy of concept analysis as a method for analysing concepts in geography. The secondary focus is on the findings revealed regarding the concepts and students examined.

There is much ambiguity surrounding the concepts of space (Meyer, 1977). The ambiguities are discussed in section A1, when it is argued that due to the centrality of 'space' in geography, the need for clarification is urgent and warrants vital concern. The concepts selected for testing and the postulated hierarchy are outlined (A2) before addressing the hypotheses and assumptions (A3). The method of concept analysis - examined in the previous chapter - is outlined in section B for the present study. The compilation of the questionnaire follows in detail in a section of its own since it is a crucial element in the study. The analysis of the results is divided into three sections: the proposed hierarchy (section D); Piagetian-type tasks (E); and tasks on the concepts of space in geography. Finally, the chapter as a whole is reviewed and the main issues revealed by the study are stressed.

A. CONCEPTS OF SPACE IN GEOGRAPHY

According to Harvey (1969), Whorf (1952) expresses concern that advances in scientific thought have resulted in a situation where different dialects or languages are evolving within disciplines. Whorf suggests that these languages are becoming mutually unintelligible, and communication which is essential for development of ideas is being hindered. One such language is the spatial language in the discipline of geography. Upon analysing concepts in geography, evidence of misunderstanding and differing interpretations associated with space become apparent, illustrating the confusion and conflict with which students of geography contend. Both the need for clarification of concepts of space emerges, and the application of concept analysis to a selection of spatial concepts is therefore required. However, it is necessary to establish whether clarification of concepts of space is inconsequential or of importance to the discipline and research endeavours, before moving on to the selection of concepts to be tested.

1. The research need

The spatial language consists of a scheme of concepts qualifying interpretations of space, for example: existential space, economic space. As noted in Chapter Two, research toward development of a science cannot be undertaken except by reference to a scheme of concepts. Differing interpretations of space may exist, but if the various meanings attributed to spatial concepts in the scheme are not made clear, the spatial language of one researcher becomes incoherent to another. The point is made clear by Lucas: "Among the cognoscenti the word 'space' trips off the tongue with the greatest of ease: phase space, sample space, linear space, Banach space - the world seems full of space, but on other occasions we still feel we want to know what space is" (Lucas, 1975, p.73). Communication required for research development becomes limited, restricting application of the advances in scientific thought. Clarification of concepts in a discipline would seem to be an integral and necessary part of the progress of thought and the more prominent the concept, the greater the need to eliminate communication difficulties. One of the prominent and distinguishing factors in geography is its spatial perspective. It then needs to be established whether there is confusion in the understanding of the concept of space and if so, to identify possible areas of misunderstanding.

The discussion lies neither with the debate on the need for a spatial concern or structure in geography nor with the question of whether it is a case of spatial fetish. Indeed, searches for spatial structure (Guillard, 1962) have been criticised in that such searches were not what geography ought to be about. The reply was simply to assert that it was (Eyre, 1973). Therein lies an indication of a lack of communication. Rather, discussion centres on defining some of the many uses of the term space, and outlining the subsequent generation of confusion from the different interpretations evident in literature.

Throughout the developments in 20th century geography, the spatial perspective has maintained its prominence, and has been manifested not in the use of a few particular concepts of space, but in an increasingly wide variety of spatial concepts. So much so, that Harvey (1969) has suggested that the history of geography is the history of the concept of space in geography. It is, however, precisely this versatility of the interpretation of the term space, which has led to much ambiguity and misunderstanding as noted by Beaujeu-Garnier (1976). There have been many calls for continual re-examination of this concept so central to geographic thought (Caruso and Palm, 1973; Gregory, 1978). The discussion thus far has established that it is important to seek clarification of central concepts and that space as a central concept in geography is evidently not clear. The question now arises as to where the confusion of interpretation lies.

Geography is often defined as the study of man-land relationships (Abler et al, 1972; Haggett, 1972), or the relationships between nature and the contribution of man, with the landscape uniting the two (Labasse, 1966). Beaujeu-Garnier (1976) asks: but what is this land or landscape? A question more readily asked than answered. Land and landscapes are interpreted and understood by the geographer in terms of a number of spatial concepts or a spatial language. For example, spatial languages used in geography may be that of absolute space language considered by geographers as those measured in fixed units such as kilometers; or relative space language - such as plastic space. Although other spatial languages have been suggested, such as objective and subjective (Welch, 1978), most interpretations of space fall into either of the two categories of absolute or relative space (Sack, 1973; Entriken, 1977).

The categories of absolute and relative space have been analysed by Beaujeu-Garnier (1976) in a close examination of the problem of space in geography. She states that at present, geographers are attempting to work with a dual system involving two languages. In the first instance, the understanding of space is that of being unchanging, physical and therefore absolute; in the second instance, the understanding is that of space as consisting of relative views, relationships, changeable aspects and hence relative. Beaujeu-Garnier's point is that geographers are confused with the juxtaposition of the two broad types of spatial categories, and as Entriken (1977) and Meyer (1977) both emphasise, there is a need to question whether two such different concept-categories of space can be held within the one philosophical framework.

Beaujeu-Garnier (1976) suggests that the 'hangover' of Kantian, and not neo-Kantian, concepts of absolute space measured by Euclidean metrics is still lingering with geographers. As in many other disciplines, geography has been dominated by Euclidean geometry to such a degree that it was never questioned as being the one and only spatial language suitable for discussing geographic problems (Harvey, 1969). In some contexts an appropriate language may exist; in others it is clear that new spatial languages need to be developed. Particularly in the latter case, clear indication of the new meaning attributed to space is important in order to avoid confusion and misinterpretation.

An example of the use of the concept of space may serve as an illustration of a danger to be avoided in versatile interpretations of space. Harvey (1976), in the introduction to a work, acknowledges using the concept of space in a particular way for the first five chapters in accordance with a definition given at the outset. After which, it is stated, the definition "...fades into insignificance ... and space becomes whatever we make of it <u>during the process of analysis</u> rather than prior to it." (Emphasis is not in original) (Harvey, 1976, p.13). Such a comment is an admission to the lack of clearly defined meanings of the concept. Not even prior to analysis, is any clear indication given as to the selection and definition of the most appropriate spatial language for the particular problem. Harvey is not alone, as Beaujeu-Garnier (1976) and Gregory (1978) point out. Despite this, it is Harvey who earlier states that, "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, p.191). Harvey's apparent failure to define clearly the conceptual frameworks for space selected in later work suggests the difficulty of the practical outworking of the point made in 1969 (Harvey, 1976).

The philosophy of geography does depend on the framework or, in the case of space, the co-ordinate system selected. Geography's philosophy has been built on the concept of absolute space, and yet the relative and relationist viewpoints are being introduced (Meyer, 1977; Gregory, 1978) without the necessary change in philosophical framework. The need for clarification of spatial concepts evidently is not simply a semantic issue, but rather a problem of communication difficulties, and misunderstanding with philosophical implications. The problems associated with concepts of space on a macro-level of relative and absolute categories has been discussed. Focus will turn now to the micro-level which will serve to identify specific examples. After which, the selection of specific concepts of space for concept analysis will be outlined.

Mathematical analysis in geography has tended to assume a Euclidean geometry, and only recently have there been explorations in the direction of alternative geometries or mathematical spaces (King, 1969). Social space is an example of an alternative, with distances measured in terms of interaction frequency, perception, and complementarity between groups (Buttimer, 1969). Other alternatives have been sought in concepts generated in other sciences. So much so, that the evolution of concepts of space in geography is to a large extent a result of development in the physical theory of the exact sciences (Harvey, 1969). Gregory (1968, p.73) states that "...many of the concepts of human geography have been modelled on those of the natural sciences. Much early science work in locational analysis and regional science was little more than social physics in a spatial context, and these comparatively simple applications and analyses have since been extended." Thus, for example, Wilson (1970, 1974) has proposed accounts of the mechanics of urban and regional systems; Isard et al (1975), explored the interpretation of space-time development models by means of classical field-theoretical models of physical phenomena; and several geographers have applied catastrophe theory in order to identify discontinuous change in space-time systems (Amson, 1974; Mees, 1975; Wilson, 1974) . Other interpretations of space are coupled with an adjective, e.g. race space (Smith, 1977); existential space (Samuels, 1978). Each of these concepts of space presupposes certain attributes about space itself. For example, some attributes include whether space is assumed infinite, changeable, or measurable by Euclidean geometry. The characteristics will then indicate to what category of spatial language the concept belongs. Rarely is explicit reference made to the underlying characteristics of a given concept. Such a neglect results in a lack of clarity regarding how the type of space can be measured, and whether the space has dimensions.

In attempting to define any particular concept of space it becomes evident that the concept of space in general is extremely complex. Thrift (1977) states emphatically that, as with time, space simply cannot be defined clearly. And it is Einstein who speaks of the difficulty of definition: "...in the case of words like 'place' or 'space' whose relationship is far less direct, there exists a far-reaching uncertainty of interpretation." (Einstein in Jammer, 1969, p.xii). Although there has been a rapid increase in interpretations of space in geography, the concepts are rarely clearly defined and rarely are the implications of the newly derived meanings fully understood (Meyer, 1977). No doubt the complexity of the concept contributes to the geographer's confusion. Nevertheless, attempts should be made to continually refine interpretations of space and explanations of terms used. One aspect of the process of refining explanations, is by establishing the meanings attributed to concepts by those who use them. It is suggested that there is a need to listen to the learner who has to cope with the lack of clarity. Concept analysis aims to elicit the student's understanding of the different concepts of space. In this way, the level of communication achieved between, on the one hand the student, and on the other hand the teacher and literature, may be made evident, exposing different levels of understanding and problem areas.

The above discussion has established a number of points:-

a) Clarification of concepts of space is important for the discipline and research;

b) There is evidence of confusion regarding concepts of space in geography;

c) One approach toward clarification is to elicit students' understanding of the concepts.

Application of concept analysis in geography is a response to the need to understand the comprehension of concepts by the students who are exposed to different and sometimes inconsistent spatial languages. Although application of concept analysis is needed for many of the concepts, a selection is necessary for the exploratory study to follow. It remains to outline below the selection of concepts for testing, and the subsequent postulated concept hierarchy.

2. The selection of concepts and a postulated hierarchy

A hierarchy of types of space is inherent in all spatial concepts. The types of space are generally referred to as topological, projective, and Euclidean (Piaget and Inhelder, 1967). Certain topological concepts are prerequisite for projective and Euclidean concepts. Examples of topological space include proximity, order, separation and surrounding which require pre-operational abilities, through to the concept of infinity which demands formal operational thinking. Projective space includes distance and location relative to other objects, and co-ordination of viewpoints. Projective space is understood when an object, e.g. a town, or a pattern such as retail delivery patterns, are no longer viewed in isolation. Finally, concepts such as ratio and scale, and co-ordinate systems such as those used in mapping comprise Euclidean space. Projective and Euclidean space are inter-dependent.

In accordance with Gagné, it is proposed that for example, the concept of relative space or relative distance cannot be fully understood until the subordinate concepts of accessibility and interaction are understood. In turn the concept of accessibility cannot be fully understood until location is understood. The understanding of concrete concepts such as physical distance would not require formal thinking. However, forms other than physical distance, e.g. economic distance, are abstract and require formal thinking. It is suggested that formal thinking is required for the understanding of economic space. The upper half of the hierarchy is comprised of concepts requiring formal thinking (Fig.4), whilst the concepts below can be understood using concrete or formal thinking. The hierarchy, questionnaire, and the postulations on which they are based will be examined in the process of concept analysis. Following the selection of concepts of space to be tested the hierarchy was constructed in accordance with Gagné's theory. The cognitive ability required to understand the concepts in the hierarchy (e.g. concrete or formal abilities according to Piaget) forms a basis for the formulation of questions or tasks set on each concept to be tested. Since Piaget's stages are invariantly sequential, cognitive ability may be characterised as hierarchical (Benefield and Capie, 1976). The demand on concept ability will increase toward the higher levels of the hierarchy. Conceptual understanding and cognitive ability (e.g. concrete, formal) of the students may be ascertained from the questionnaire responses. The ability to perform correctly on questions at a particular level indicates a high probability of correct performance on the next higher level. The concept of economic space is selected as the terminal concept for the hierarchy. It was chosen as a result of the lack of clarity perceived in geography texts, and from evidence that students have difficulty using the concept in written work and discussion.

A survey of geography texts and discussions was used to aid in the reduction of the terminal concept of economic space into a series of sub-concepts from which it was derived. Below is a postulated concept hierarchy for the concept of economic space (Fig.4). Concepts range from the simplest at the lower levels, to the more complex at the higher levels. Although no single hierarchy is independent of any other concept hierarchies, the attempt has been to isolate those concepts considered as prerequisite for the terminal concept of economic space. The questionnaire (Appendix A) was designed using the hierarchy as a basis for question formulation.

3. The hypotheses and assumptions

The hypotheses were developed on the basis of the main tenets of Piaget and Gagné. As the following discussion shows, the first hypotheses were formed as a series of five, and are in accordance with Piaget's theory; a single hypothesis was formed on the basis of literature on the geographical spatial perspective; and finally a series of seven were formed in accordance with Gagné's theory.

Previous research has established that over one third of adults and students in America do not use formal thinking (Fuller, Karplus and Lawson, 1977). If their findings characterise South African students, then many of the concepts of space which are taught will not be understood by over a third of the students. A battery of empirically well-accepted Piagetian-type tasks is used to elicit students' abilities to exhibit formal thinking on a range of tasks. The Piagetian-type tasks selected were those which tested general concepts of space. Tasks testing aspects of topological, projective and Euclidean space were selected since they represent types of space which are inherent in the concepts of space in geography. One final task, the Islands puzzle, which tested abstract reasoning was used since it tests the form of reasoning required by all sciences.

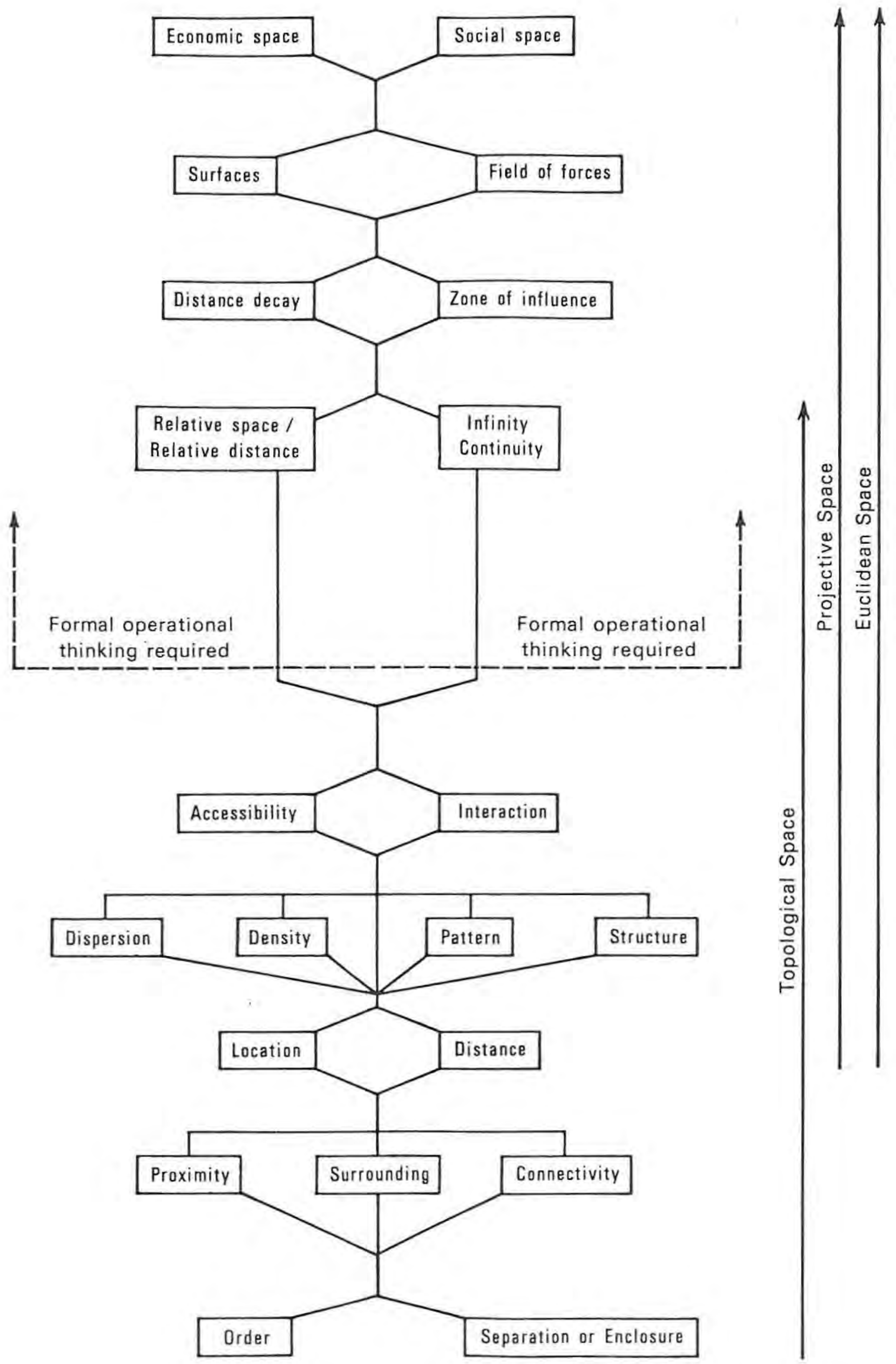


Figure 3: A postulated hierarchy of the concepts of space.

H I : There will be students in the sample unable to exhibit formal operational thinking in the tasks on an aspect of topological space.

H II : There will be students in the sample unable to exhibit formal operational thinking in the task on aspects of projective space.

H III : There will be students in the sample unable to exhibit formal operational thinking in the tasks on aspects transitional between projective and Euclidean space.

H IV : There will be students in the sample unable to exhibit formal operational thinking on the puzzle testing abstract reasoning ability.

Hypothesis on the basis of geographical literature on concepts of space.

H V : Students in the sample will have misunderstandings regarding the selected concepts of space in geography.

If students are experiencing difficulties with concepts of space in geography, there will be students who have misunderstandings or in some cases misconceptions. The questionnaire is analysed for each student individually, tracing thinking patterns and noting recurring misunderstanding.

Hypotheses on the basis of Gagné's theory.

In order to ascertain whether a hierarchy of the concepts exists, the following statement needs to be tested. Within a sample, all the students who understand a certain concept are a sub-set of the students who possess a prerequisite concept (White and Clark, 1973). Seven pairs of concepts in the hierarchy were selected to be tested for dependency. The seven hypotheses formed were worded identically as follows.

H VI - XII : Those students with skill II are totally included among those with skill I.

Where : Skill II is the upper concept in the hierarchy, Skill I is a proposed prerequisite concept.

: Those with a skill are those who answer correctly two questions on that skill out of two.

The statistical test applied to the pairs of concepts was that derived by White and Clark (1973). The test is the only hierarchy validation test developed which allows for errors of measurement. Two or more questions need to be used for each skill. A full explanation of the test is given in the analysis.

A subjective analysis of the hierarchy is also conducted. Such an analysis enables detail to emerge and relationships between concepts in terms of the students responses to be noted. It needs to be stated that although an expensive procedure, analysis of each student's performance on the concepts of the hierarchy is essential if the analysis is to be accurate.

Assumptions

Three assumptions need to be made at the outset.

i) There is a hierarchy of complexity of the concepts embodied in the concept of economic space;

ii) Concepts in the hierarchy can be classified as requiring formal or concrete thinking according to Piaget's theory;

iii) Piagetian tasks in the questionnaire serve as control tasks (or well-accepted standards) discriminating concrete and formal thinkers.

Section A has focussed on the concepts of space in geography, and how the problems encountered in the concept meanings are integrated into the case study. This was begun by reference to difficulties concerning concepts of space in geography which presented the need for research. The selection of concepts to be part of the study was made, and a hierarchy postulated. On the basis of these, and utilising the theories of Piaget and Gagné, hypotheses were formed and assumptions made. The research design which follows provided the framework which assimilated the above in the case study.

B. RESEARCH METHODOLOGY

The central aim in concept analysis is to examine the adequacy - however defined - of a concept, and to attempt to identify reasons for the level of adequacy achieved by the student. No study in geography has yet employed Piagetian and Gagnéan theory in the analysis of concepts. Hence the research methodology employed to examine adequacy of understanding of concepts and to explore possible reasons for the levels of adequacy displayed is adopted from research in other disciplines. This new approach in geography to the study of concepts is adopted firstly, by determining what level of cognitive ability the selected concepts demand for adequate understanding to be obtained. Secondly, students responses are classified as demonstrating pre-operational, concrete, or formal operational thinking. The case study is primarily concerned with examining concept analysis as a possible method to be used to confront conceptual and cognitive issues in geography as have been raised. The study has three aims. The first is to apply the theories of Piaget and Gagné and discuss on an empirical basis the efficacy of the method used. The second aim is to reveal misunderstandings concerning the concepts of space selected for testing; and the third aim is to discuss results with a view to further applications of concept analysis in geography. The research methodology employed for the study will be traced under the headings of 'Research strategy', 'The interview' and finally an explanation of the validation test under 'The hierarchy validation technique'.

1. Research strategy

On the basis of the aims, hypotheses and assumptions, the methodological procedure followed the steps listed below.

a) The second year geography students at Rhodes University were selected for the study. All the students were tested, numbering thirty-eight. Second year was chosen since the students would have been subjected to university teaching methods for at least one year, and would have encountered the use of 'space' in geography in texts, lectures, and essay topics. The number of students tested was small, but this is not out of keeping with other exploratory studies referred to previously (e.g. Mannino et al, 1973; Howe, 1974; Kolodiy, 1977). As a result qualitative and statistical tests and trends cannot be used to draw clear conclusions. Rather, the tests and trends discussed in the analysis are used as guidelines for future research.

b) The questionnaire (Appendix A) was drawn up, based on the postulated hierarchy, and consisting of a series of questions on selected prerequisite concepts and the terminal concept of economic space. The question-types were classified as requiring formal and concrete thinking. A selection of Piagetian control questions was included, found through empirical tests to be reliable indicators of concrete and formal thinkers. The questionnaire was administered to ten first year and ten third year geography students of Rhodes University as a pilot study, with each student being interviewed. The first and third year students were selected in order to keep the number of second years participating in the final study as large as possible. Second years from another university were considered as inappropriate for a pilot study, since teaching methods and concepts taught could introduce unknown factors in terms of why students responded to questions as they did. Also, first and third years at Rhodes University served as regulators: the questions being able to be understood by the first years; both first and third years' responses indicating the appropriateness of levels of difficulty, and whether the questions actually tested what they were intended to test. The questionnaire was then modified accordingly, and checked by three geographers for verification.

c) The questionnaire was then administered to the second year geography students at Rhodes University in a classroom situation.

d) The questionnaires were analysed and interviews conducted with all whose questionnaires were analysed, in order to overcome some of the limitations of the questionnaire method (e.g. ambiguity; reasoning behind particular answers).

e) According to performance on the questionnaire:-

i) students' responses were classified as exhibiting concrete or formal thinking and the hypotheses were considered;

ii) common misunderstandings were isolated and their possible origins within the hierarchy suggested, and the hypothesis tested;

iii) relationships were examined between misconceptions, and the ability to perform concrete or formal tasks;

iv) a hierarchy validation technique, explained in the analysis, was applied to the hierarchy, discussed, and the hypotheses were tested;

v) the hierarchy was examined in the light of results of validation technique, and possible modifications to the hierarchy suggested.

Analysis of questionnaire performance was in accordance with the theories of Piaget and Gagné, summarised in Figure 4 , and hypotheses were accepted or rejected on the basis of results. A brief explanation of Figure 4 will outline the path of analysis taken. For example, if a student is found to have an inadequate understanding of the concept tested, questions are

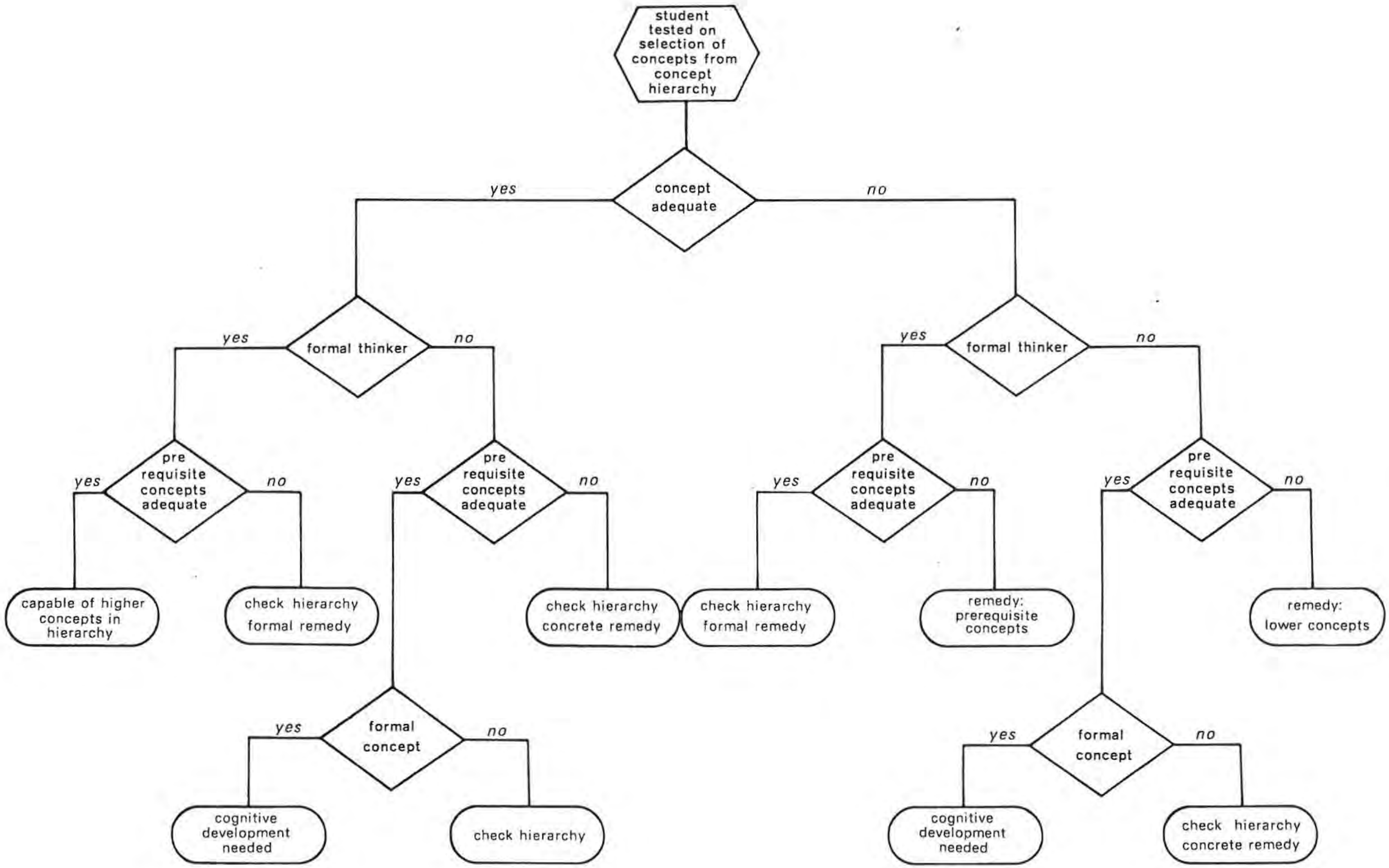


Figure 4: A research strategy for concept analysis adapted from the theories of Piaget and Gagné.

raised as to the reason for inadequacy. If the student does not exhibit formal thinking on Piagetian tasks, then it is assumed that cognitive development may be necessary, particularly if the concept being tested is formal. From the students' responses it is ascertained whether the prerequisite concepts are adequate. If they are not, then it would seem that remedial action would be to first understand the prerequisites. If the student does exhibit understanding of prerequisites, then two possibilities are raised. Should the concept being tested be formal, then for the student who does not exhibit formal thinking, cognitive development may be needed before understanding is possible.
Alternatively, if it is not a formal concept being tested, the hierarchy may be invalid - i.e. incorrect relationships proposed between concepts, or the question types do not elicit accurately the student's understanding. However, if it has been correctly deduced that the student does not exhibit concrete thinking on the set tasks then the contribution of the research would be to indicate that any remedial procedure needed to be within the bounds of concrete ability. The interviews aided greatly in clarifying the extent of the students' understanding. The details of the interview technique need to be given.

2. The interview

Osborne and Gilbert (1979) investigated concept understanding of science students and explored the question: "How can concept understanding be effectively investigated?" (Osborne and Gilbert, 1979, p.13). In response to the question, Osborne and Gilbert (1979) developed a method called interview-about-instances (I.A.I. method). The I.A.I. method requires the student to categorise given instances as exemplars or non-exemplars of a concept. The interview, as opposed to a questionnaire alone, allows each of the students' answers to be discussed, in order to trace the students' reasoning behind his answers. The interview also allows the opportunity for any perceived or actual ambiguities to be cleared.

The I.A.I. method for investing concept understanding influenced the present study, in the form of multiple choice questions which require the student to identify instances belonging and not belonging to the concept. In the interview, each of the students' answers was discussed and the student was able to ask any questions necessary about ambiguities. The questionnaire employed question types other than those suggested in the I.A.I. method. The varied question types allowed concepts to be explored from a number of angles. The full reasons for the selection of question types are outlined in the section on the compilation of the questionnaire. The interview also aids in determining whether incorrect answers on different types are due to insufficient reading and writing skills. Further advantages are mentioned by Osborne and Gilbert (1979). For example no question can easily be ignored, hence when the student answers that he does not know, the reasons for this can be explored. Similarly, the student cannot easily refuse to explain his answer, and any guessing becomes clear. Finally, the interview can reveal whether the student has given the right answer for the wrong reasons, or vice-versa.

Advantages of interviews as a technique have been mentioned above. There are several difficulties involved in interviews as a technique. Good interview technique comes with experience - the implications here are twofold. Firstly, any teacher wanting to conduct similar work to explore the degree of effective learning taking place in his course needs first to do some self preparation. Secondly, for this study the researcher was aware that the interviews flowed with greater ease after the first several interviews, despite the pilot study interviews having been conducted. The effectiveness of the interviewer, therefore may increase with experience. The extent to which such a chance would effect the results in this study is difficult to ascertain, and has been assumed as negligible. Another area of difficulty was pointed out by Piaget (1967) as being one which persisted with the most experienced interviewers. The difficulty is that of not suggesting answers by either verbal or body language, whilst neither inhibiting nor confusing the interviewee. There is a final caution to be noted regarding the interview:
When using a series of identical questions it became evident that it becomes easy to anticipate the students' response along the lines of the several students already interviewed. Such anticipation could result in unintentionally guiding the student's thinking along a particular route which is not his own. Encouraging the interviewee to initiate comment, for example after a moment of silence, rather than prompting from the interviewer was used as one way of reducing the likelihood of directing his thinking. A brief outline of the way in which the interviews were conducted in this study now follows.

The researcher conducted interviews with every student who completed a questionnaire. Each interview lasted between fifteen and twenty minutes. The interviews were conducted keeping to a battery of questions where the wording for each student remained the same. The student's questionnaire which had already been carefully examined in detail, was brought out at the interview. The interviewer began each interview by emphasising that the questionnaire had nothing to do with examination records, but rather that the interviewer was interested in "...how you as a student see things". Students were generally put at ease by this emphasis. As with Osborne and Gilbert's (1979) experience, focus on something else - in this case the questionnaire - by both interviewer and interviewee rather than on each other contributed to a more relaxed atmosphere. The student was asked if the interview could be taped and then transcribed in order to lose as little of the interview as possible. All students agreed. Each question was first read aloud either by the interviewer or the interviewee (some students felt relaxed enough to take such initiative) whilst the others read silently with them. The interviewer then began the discussion by referring to the student's answer, for example: "I see you selected answer b). Could you tell me more about your thinking here?" Depending on the particular question, a certain battery of questions was then asked similarly for each student. The student was encouraged to think aloud whilst working through a question or thinking through the explanation of his answer which shows the student's reasoning (Cowan, 1977); and also to discuss any thoughts that came to his mind. The majority of students seemed to relax during the interview, showing interest in other students' reasoning, offering useful unsolicited comments, asking at the end to be shown other ways they could have answered, and wanting to know why they had the tendency to reason in a particular (incorrect) way. The last of these the researcher was unable to answer in any depth, but the questions demonstrate the readiness and desire to learn when students' reasoning patterns are pointed out to them. A few students came to realise in the interview why they had 'mental blocks' about some of the concepts. The 'blocks' tended to be due to faulty reasoning and to hierarchical problems.

More will be said about these students in the analysis of the responses, and more about the results of the interviews will be discussed as the interviews are referred to in the results. The interviews and questionnaires (the latter is discussed in section C) comprise the qualitative analysis of the hierarchy. The quantitative techniques for hierarchical analysis are still being investigated and improved. The particular technique chosen for testing the postulated hierarchy is interpreted below.

3. The hierarchy validation technique

Objective tests of validity for learning hierarchies are still being developed and the available indices used are under debate concerning reliability (White, 1974a;Hofmann, 1977). In 1973, White stated that due to flaws in techniques, to that time "...no meaningful qualitative conclusion has been reached about the validity of even one step in any hierarchy" (White, 1973, p.371). A technique proposed by White and Clark (1973) is reputed by White (1974) to have overcome many of the shortcomings of other techniques such as those by Guttman (1944), Gagné and Paradise (1961), and Walbesser and Eisenberg (1972). White and Clark's (1973) 'test for inclusion' was selected for the study rather than other techniques which are not satisfactory in one or more of the following areas: errors of measurement are not considered; subjective decisions need to be made; or the indices calculated have been shown in some cases to validate a hierarchical connection between pairs of concepts when the concepts are independent and unrelated (White, 1974). Although research in this area continues, since White and Clark's (1973) technique no other improvements or newly proposed tests had been published by 1979 for application to concept hierarchies. The 'test for inclusion' will be outlined in full below. In the discussion of the results, problems encountered in White and Clark's (1973) technique will be included.

The test requires that two or more questions are used for each concept, since only one question does not allow for an estimate of the size of errors of measurement to be made. The concepts will be referred to as skills, since ability is required to understand a concept, and the term skill is in keeping with the terminology adopted by White and Clark (1973). Skill II refers to the higher skill in the hierarchy, and skill I to the lower in each pair of skills considered. The test concentrates on those students who answer correctly all the questions on skill II, yet answer incorrectly all the questions on skill I. The concentration is on this group of students since a valid hierarchy would minimise the number in the group, the ideal being to have no students belonging to the group. When there are students in this group, then a critical number needs to be determined, above which the hierarchical connection is stated to be invalid. The critical number is determined from the reliability of the questions for each shown, and from the probability that the hypothesis that the connection is hierarchical is wrongly rejected. The steps in the technique are listed below and explained.

A matrix is drawn, with the observed number of questions answered correctly: 0, 1 or 2 for skill II are given on the horizontal; and for skill I on the vertical, with 0 at the lower and 2 at the upper edge of the matrix. Proportion and probability parameters are derived from the marginal totals from the matrix. The proportions (P) and probabilities (O) express the probability that a randomly selected student from the sample answered correctly zero, one or two questions for either skill. The derivations of proportions are as follows:

The proportions (P) are estimates for a population, where the proportion of the population with neither skill I or II is P_o,

with skill I only is P_I ,

with skill II only is P_{II} ,

and with both skills is P_B .

The derivations of probabilities are as follows:

The probabilities θ are estimates for a population. Let the estimated probability of a number of the population with skill I answering correctly either of the questions for skill I be θ_a , and the probability of someone without skill I answering correctly either question for skill I be θ_b. Let θ_c and θ_d be corresponding probabilities for skill II.

The hypothesis is that those with skill II are totally included among those with skill I, and is stated as:

$$H : P_{II} = 0.$$

In other words, if there is a hierarchical relationship between skill I and skill II, with Skill II being the higher concept, then according to Gagné, all those students with skill II could not have attained it without having skill I.

The assumptions need to be listed here, before the equations for O and P.

a) Assume that the chance errors on the two questions asked of each concept in the concept pair are independent of one another.

b) Assume that the probabilities of chance errors are equal for the two questions on each skill.

c) Assume that the two questions for each skill would both be answered correctly or both incorrectly by all members of the population if it were not for chance errors of measurement.

d) Assume that all the tested members who scored only one on skill I were actually capable of scoring two but were victims of chance error. Also assume that tested members who scored one on skill II were capable of scoring zero only, but scored as a result of chance or guessing. This means that $\theta_b = 0$, and $\theta_c = 1$.

The equations for O and P will now be given. It is necessary to note at this point, however, that values for O and P need to be estimates rather than observed values, estimates being expressed as $\hat{O}$ and $\hat{P}$. Because of errors of measurement will always exist, there are two possible strategies to counteract their effect. The one is to ask a large number of parallel questions for each skill. The larger the number, the greater would be the resultant division between those who possessed the skill, and those who did not. And the greater the division, the less would be the chance of error in stating whether a skill was possessed or not. Such a strategy is time consuming, difficult to construct, and responses to the questions could be affected by learning or boredom (White and Clark, 1973). The alternative strategy is to estimate the probability with which the numbers of tested members observed to possess skill II but not skill I could have occurred under the conditions of $H : P_{II} = 0$. Calculation of such an estimate requires two or more questions to be asked for each skill. The equations for estimates are as follows.

$$\hat{\theta}_a = \frac{2a}{2a+b} ,$$

$$\hat{\theta}_d = \frac{e}{e+2f} ,$$

and assuming: $\hat{\theta}_b = 0$,

$$\hat{\theta}_c = 1 .$$

Also, $\hat{Q} = \frac{(2a+b)^2}{4aN}$,

$$\hat{R} = 1 - \frac{(e+2f)^2}{4fN} ,$$

where $\hat{Q} = \hat{P}_I + \hat{P}_B$, proportion of population with skill I

$\hat{R} = \hat{P}_{II} + \hat{P}_B$, proportion of population with skill II

N : sample size.

To find the values of $\hat{P}$, the value of $\hat{P}_{II}$ under the hypothesis is chosen. In this case, $\hat{P}_{II} = 0$.

Since $\hat{P}_o+\hat{P}_I+\hat{P}_{II}+\hat{P}_B = 1$,

then under $H : P_{II} = 0$,

$\hat{P}_o+\hat{P}_I+\hat{P}_B = 1$.

The values of $\hat{P}$ are therefore found by substitution in the above equations:

$$\hat{P}_B = \hat{R} ,$$
$$\hat{Q} = \hat{P}_I+\hat{P}_B ,$$
$$\hat{P}_I = \hat{Q} - \hat{R} ,$$
$$\hat{P}_o = 1 - \hat{Q} .$$

The cell containing responses to skill I as 0, and to skill II as 2 (0-2) is the critical cell of the matrix in terms of the hypothesis. Therefore the probability of the response of a randomly selected member from the sample being 0-2 (P_{o2}) needs to be calculated. The equation for this is adopted by White and Clark (1973) from the method described by Rao (1965, p.305):

$$P_{o2}=P_o(1-\theta_b)^2\theta_d{}^2+P_I(1-\theta_a)^2\theta_d{}^2+P_{II}(1-\theta_b)^2\theta_c{}^2+P_B(1-\theta_a)^2\theta_c{}^2 \quad .$$

The cumulative probability for the observed frequency of 0-2:$P(fo_2)$ can be calculated using the multinomial expansion, viz:

$$P(f_{o2}=0) = \hat{p}_{o2}(1-\hat{P}_{o2})^N$$
$$P(f_{o2}=1) = N\hat{p}_{o2}(1-\hat{p}_{o2})^{N-1}$$
$$P(f_{o2}=2) = \frac{N(N-1)(N-2)}{3 \times 2}\hat{P}_{o2}{}^3(1-\hat{P}_{o2})^{N-3}$$

etc.

Then the first number n* is found, such that:

$$P(f_{o2} \geqslant n^*) = 1-\left[P(f_{o2}=0)+P(f_{o2}=1)+....P(f_{o2}=n^*-1)\right] \leqslant 0,05$$

Then if $f_{o2} \geqslant n^*$ reject Ho at 5% level.

In summary then, a valid hierarchical connection between a pair of skills exists for a population if no member can understand the higher skill without having first understood the lower prerequisite skill. The technique described above was presented by White and Clark (1973) as a test for hierarchical dependence which overcomes the insufficiencies of previous tests in that it is objective, and allows for errors of measurement. Before dealing with the results and the application of White and Clark's (1973) technique, details of the questionnaire need to be given since the results depend upon the questionnaire. Description and analysis of results then follow, concluding with a precis and evaluation of concept analysis in geography with a view to further research.

C. COMPILATION OF THE QUESTIONNAIRE

The discussion on the spatial perspective in geography outlined problem areas in the understanding of concepts of space, which formed the basis for construction of the hierarchy. The next step was to test students' understanding of certain concepts and the validity of the hierarchy. The testing method selected was that of submitting a questionnaire to a sample of students. The questionnaire was compiled by formulating questions about concepts selected from the hierarchy. A pilot study was conducted, and appropriate changes made. An examination of the rationale behind each question will bring to the fore the intentions and aims in each task.

1. Pilot study

A pilot study was conducted, with a selection of ten geography I and ten geography III students. The students were selected from university examination records available for geography I and geography III students in order to sample a range of student abilities in both years. Also a balance between male and female was sought due to the varying conceptual capabilities reported between sexes (Elkind, 1962; Graves, 1975; and Za'rour, 1975). During the interviews and whilst completing the questionnaire the students were invited to discuss difficulties experienced in answering questions, including ambiguities, no alternative available for a certain category in multiple choice, and in terms of level of difficulty and length of the questionnaire. As a result of the pilot study, some questions were isolated as ambiguous, and alternative wording was discussed with the students. Also, one exercise was eliminated because it was not clear what the exercise was actually testing.

The modified questionnaire was then given to three geographers for feedback, since Osborne and Gilbert (1979) suggest that opinions from experienced teachers in the discipline are important and useful. One geographer was from Rhodes University, and two geographers were from separate universities, who indicated interest in the study. There was consensus of opinion amongst the geographers as to the reasonableness of the demands made by the questionnaire on the student, and the potential usefulness of the tasks set. A detailed rationale for each task in the modified questionnaire needs to be given.

2. The final questionnaire

The choice of question types (e.g. multiple-choice, open-ended) requires careful attention. As mentioned in the discussion on research strategy, each questionnaire respondent was interviewed. However, a danger with both questionnaire and interview techniques is that ordering and wording of questions and the question types may manipulate or force the student to respond in a particular way. Question order and type is first dealt with, followed by administration, information required, and then a question-by-question rationale is given.

a) Question order and question types

The questionnaire may be referred to in Appendix A and is divided into two major sections. The first questions (Q1 i-iv) are short, intended to be clear and relatively simple so that the students may gain confidence in what will be essentially an unfamiliar type of questionnaire. The next task involving the model landscape (Q2A) gives the student something visual to work with, not requiring a high degree of abstraction. Following the questions relating to the baker's travel in the model landscape, a puzzle is included (Q2B). Although the puzzle has been used in slightly different forms as a fairly sophisticated method of eliciting students' formal abilities, (Phillips, 1977), it appears to be an interest-provoking rather than threatening exercise for the students. The pilot study revealed this to be the case.

The concepts of social space (Q2C i)followed by geographic space (Q2C ii) were then included, introducing the student gradually to the two concepts before later asking questions on economic space, which is the terminal concept in the hierarchy. Scale (Q2C iii) is a familiar concept to all students, being taught in the first term to geography I students, and used frequently thereafter in other exercises. Scale is introduced prior to a rather difficult series of questions on space (Q3 i-iv). The questions on economic space (Q4 i-iv) are then introduced, by which time the student should be more at ease with the question types.

Economic space, being the terminal concept examined from the hierarchy, has an important role in the analysis. It is important therefore that the students are given an opportunity to begin to derive a level of understanding and familiarity with what are unusual question types. There is a possibility that had the concept of economic space been included earlier, students would not draw on as many answers given to previous questions. It is felt however, that if the student is able to use the information elicited by previous tasks to advantage, credit is warranted, since under text book or lecture situations, concepts are couched in a particular context from which the student would derive meaning. Contextual thinking itself is not to be discouraged. The questions on economic space conclude Section I of the questionnaire.

The series of questions in Section II are concerned with general concepts of space, and are a selection of Piagetian control questions (Q1-5). The Piagetian tasks have been found through empirical tests to be reliable and valid indicators of pre-operational and operational abilities. Although the puzzle task and the question of scale are also applications of Piagetian theory, they were included in Section I. The puzzle and scale tasks were introduced earlier than Section II because of the type of question - discussed above - and to make multiple use of the model landscape diagram by placing the questions close to the diagram for convenient reference. Nevertheless, both the question of scale and the puzzle would be readily associated with geographical implications, unlike those in Section II, apart from the reproduction of the model landscape in Section II (Q5).

The sketch of the model landscape was included last, as a relatively interesting and not unfamiliar task, where the student could finish the sketch in his own time without the pressure of further unknown tasks yet to answer. The mention of time leads on to the method of administration of the questionnaire and time limits imposed.

b) Administration of the questionnaire

The questionnaire was administered to the thirty eight geography II students during lecture time in a classroom situation. The explanatory paragraph given on the first page of the questionnaire was read aloud, with all students following on their own questionnaires. It was emphasised that the questionnaire had nothing to do with their class records, and that it was confidential. The questions on required information (age, course, sex, etc.) were worked through together. Before beginning Section I, the students were told there was to be no consultation with other students or books; and they could take as much time as they needed. The students were under supervision until all questionnaires had been completed. The lack of a time limit was to ensure that pressure of time would not prevent the student from clearly demonstrating his understanding. The time spent by second years ranged from thirty to forty eight minutes. The administration to the geography II class was made identical to that of the pilot study.

Finally, although each question is dealt with below individually, further detail on each question will be discussed during the analysis of results, where actual samples can be referred to, illustrating response-types. For discussion of each task, however, detail is selected to state clearly the aim and rationale behind each question.

c) Required information

The rationale for the information required in the questionnaire prior to Section I needs a brief discussion.

i) Sex. Much work has been done in the field of Piagetian studies illuminating differences in performance on cognitive development tasks between sexes. In most cases (Lawson and Renner, 1975) males seem to perform better on formal operational tasks than females. Although such a trend appears to vary between cultures (Welch, 1977) no conclusive evidence is available. What is evident is that males and females do think differently, use different operational modes, and perform differently on set Piagetian or conceptual tasks. The implications are threefold. Firstly, teachers of all levels need to be aware of the possible differences in ability. Secondly, teaching approaches should be structured in accordance with the student population.

Thirdly, explanations and remedial action need to be reviewed and administered with awareness of possible differences between sexes.

ii) Faculty. Different disciplines demand different modes or levels of thinking. Most subjects of the exact sciences require formal thinking for basic concepts in first year university (Lawson and Renner, 1975). There is a possibility that those students registering for B.Sc. do so because they are adept in the exact science subjects, suggesting they are capable of some degree of formal thinking. There is as yet, however, no conclusive empirical evidence from comparative studies for differences in ability between students in different faculties. The information was required in the questionnaire in order to discover whether any differences in performance on the questionnaire could be attributable to faculty of registration.

A further reason for requiring faculty information involves the concepts being tested - those of space. The exact sciences, in particular mathematics and physics, define physical space with precision, and there are universally accepted notions of space within the disciplines, as outlined in the previous section on spatial concepts. On the other hand an arts student who is not registered for an exact science subject, has not been subjected to such notions at university level. As previously indicated, geographers tend to use the concept of space loosely, and also adopt physics concepts, the implications of which are apparently not clear to the geographer (Gregory, 1978). It would seem dangerous, then,to adopt a concept which was originally created in a particular context. The questionnaire may aid in determining whether B.Sc. students, whilst more at ease with the concept of space as used in exact sciences, are more confused by its loose usage in geography. The B.A. student, having less of such knowledge, may be unaware of the inherent contradictions in the use of the concepts in geography, and appear to be more at ease with such a concept and its loose usage.

iii) Geography at school. Although there is little empirical evidence indicating a relationship between university performance in geography and previous geographical education, a preliminary study (Welch, 1977) suggests a tentative influence. For some of the concepts tested, it appeared that those with Std 8 geography demonstrated greater understanding than those with Std 10. A possible reason was that misconceptions were reinforced by Std 10, and use of pseudo-examples for explanations at school could have attributed to the misconception process. There is evidence from physics education research that university students often need to unlearn misconceptions gained during school physics education (Helm, 1978). The questionnaire seeks to reveal whether a similar evidence of misconceptions for the concepts of space exists.

iv) Name. Although there are advantages in respondents remaining anonymous in terms of frank answers, the respondent's name was considered necessary for recalling the student for interviews. Lovell and Lawson (1970) suggest that the respondent being required to give a name, in conjunction with a class-room administered test, lessens the number of non-responses on individual questions.

v) Code. Codes were used for data processing, the name being used for interview purposes only.

vi) Academic year. The students were told that academic year referred to that for geography. This would avoid a situation where a student is in his third academic year, whilst carrying geography I or geography II.

vii) Age. Piagetian theory refers to age as opposed to standards or academic level. Age was therefore considered important if any conclusions were to be drawn with regard to trends of concrete or formal thought.

d) Rationale for the questions concerning the selected concepts

The questions are not discussed in the order in which they appear in the questionnaire, but rather grouped according to similar themes in the rationale for each question. An abbreviated form of each of the questions is given for convenient reference; the complete questions will be found in Appendix A : the questionnaire.

i) Section I Question 1 - Instructions

Question 1

Briefly explain what you understand by the following concepts:

i) Location (e.g. of an industry)......

ii) Distance ....

In what units can distance be measured?

....

iii) Interaction ....

In what ways can interaction be measured? ....

iv) Proximity ....

Name some factors which influence proximity ....

v) Accessibility ....

Name some factors which determine accessibility ....

vi) Distance decay ....

The instruction was intended to evoke what the student understood by the concept, rather than encouraging recall and a response of wanting to give 'what was wanted' by asking the student for a definition. The instruction was considered less inhibiting than a request for a definition, encouraging greater freedom of expression.

Lunnon (1969) suggests that a brief explanation or definition of the concept indicates what the student feels is subordinate and what is most important in the understanding of the concept. The researcher can refer to the postulated hierarchy, as well as to other responses which are related to the concept being explained. It is important to note that whilst a student may be able to give correct responses to other question types referring to a particular concept, to define or explain that concept could be difficult if the student has only an intuitive grasp of the concept. Such findings are important in themselves, and do not render the question-type invalid.

Requiring an explanation or definition of a concept demands concrete thinking (Klausmeier et al, 1974), but is inadequate as a single indicator of the level of understanding. The responses need to be considered in relation to other questions. All concepts tested by question 1, are embodied in questions and concepts later in the questionnaire. Where possible, however, for each concept a subsidiary question was asked in terms of units of measurement or influencing factors, serving to clarify the explanation given on the concept. The subsidiary question was also intended as a check, in terms of inconsistency with the explanation, contradictory to explanation, or to indicate whether the student was able to reproduce a learned definition without understanding the concept fully.

ii) Section I Question 1 - The concepts. Each concept selected will be outlined briefly below following a few general points which need to be made at the outset. Selection of the concepts was made from the postulated hierarchy. Not all concepts in the hierarchy could be tested, due to the limit of time available, but as an explanatory study, a sample of concepts to be tested was deemed necessary in order to explore the possibilities of further application of concept analysis. The concepts are not introduced for testing in the order in which they appear in the postulated hierarchy, thereby reducing the possibility of the previous concept being relied upon as an explanation by the respondent. However, the concepts do range from the easier and more familiar to the more difficult, and the selection includes concepts ranging from concrete to formal. By introducing the concepts without any particular context, it is intended that the student should indicate the scope or range of his understanding of the concept as it could be used in different contexts. It is further realised that such a question form may elicit the student's initial reaction and understanding of the concept. Although the consequent written reply may indicate a more confined understanding than the student actually possesses, the response would nevertheless demonstrate that interpretation with which the student is most familiar. It is suggested that it is with the familiar understanding that the student reacts to the use of the concept encountered in literature and lectures. Knowledge of such understandings held by students is important for communication between teacher and student, and therefore educational methods.

In the light of the previous section on the concepts of space in geography, trends in responses are important in the analysis. For example, a student's interpretation of the concept of space may be absolute or relative, objective or subjective (Welch, 1978). The subsequent understanding of any of the concepts listed in Question 1 should be consistent with the student's view of space. Distance, for example, may be explained by the student in absolute or relative terms, objective or subjective terms. If the students have, as have geographers in aggregate, adopted all four modes of spatiality, their explanations would include evidence of the four interpretations.

The interpretations expressed and understood in physical terms, require concrete thinking. In other words, the student relies on that which is tangible as a basis for thought, and finds difficulty thinking in theory. Interpretations expressed in abstract terms, would indicate a level of formal thinking on the part of the student. In which case, the student is capable of understanding and explaining relationships which may be neither visual nor tangible, and can think in an abstract manner.

The ability to produce an explanation is only an indication of the student's potential ability to use the concept in a meaningful way. Question 2A, concerning a baker's delivery patterns in the given model landscape, attempts to elicit the student's ability to use some of the concepts previously tested in Question i (viz. distance, interaction, accessibility and distance decay).

iii) Section I Questions 2A i and ii - Instructions and alternatives offered.

Question 2

The diagram of a model landscape ....

A (i) ...In <u>explaining</u> the baker's delivery patterns, which one of the following considerations would you feel to be the most important?

(a) Likelihood of delivery is reduced ...

(b) Distance has a friction effect ...

(c) Cost and distance involved, or

(d) Cost and time involved.

(ii) In what units should the baker have measured the distance ...?

(a) Kms

(b) Kms plus altitude

(cont.)

(c) Cost and time of travel

(d) Kms plus cost and time of travel

(e) Km^2

The questions were presented in multiple choice form, which was selected in terms of the strengths of objective tests as outlined by MacIntosh and Morrison (1969). The strengths include relatively high degree of objectivity in marking; the speed and accuracy of marking; predetermined classification of possible answers, and the ease with which the results could be processed by the computer. To choose from a number of alternatives is a realistic task, (Chamberlain, 1974) but for selection to be meaningful ambiguity needs to be avoided. Selection of distractors was based on possible misconceptions, following Doran's (1972) work, which will be assessed according to their popularity as a choice for the correct answer. Multiple choice questions have been deemed effective in concept analyses by Za'rour (1975). In the analysis, it is necessary to be aware of the disadvantages of multiple choice techniques.

Subjective decisions are involved in the selection of the alternatives - both the correct, and the distractors (MacIntosh and Morrison, 1969; Ebel, 1972). Predetermined answers restrict the respondent's freedom in expressing his knowledge (Chamberlain, 1974). In order to lessen the degree of restriction, students were told at the outset they could write comments to justify their choice if it was felt, for example, that an alternative could be accepted only on a conditional basis. Although such comments are not possible to take into account in the processing of alternatives chosen, comments aid in the interpretation of results. Difficulty is also encountered in constructing distractors which are plausible, and discriminate between those who do not have a command of the knowledge, and those who have a better command (Ebel, 1972). The more homogeneous the alternatives, the higher the level of understanding tested. Further weaknesses include the encouragement of guessing, and the possibility of testing only factual recall and recognition. In order to overcome the latter two weaknesses, the statement "Do not guess" was included in the introductory paragraph on the questionnaire. Further, the inclusion of Question 2A ii was intended to act as a check for consistency with answers in 2A i, requiring a little more than just factual recall.

Furthermore, a comparison of answers in Question 2A ii with those in Question 1 will indicate inconsistencies and inadequate understanding of the concepts involved.

In the stem, or introductory section prior to the given alternatives, the term 'explaining' was used. The term was used in order to remain consistent with Question 1 instructions, and the need to explain indicates that an element of reasoning is required. The understanding of influences of economic aspects such as cost and time has been tested in Question 2A. A further testing of the application of understanding of economic aspects comprising distance is tested in Question 4 which deals with economic space. It is assumed from the postulated hierarchy, that an ability to answer Question 2A correctly is prerequisite for an understanding of economic space. Relationships between individual students responses to Questions 1, 2A and 4 will be examined during the analysis to identify any possible misconceptions, common inconsistencies between answers, and to examine the validity of the postulated hierarchy.

iv) Question 4 - Economic space

> Question 4
>
> For the concept of economic space:
>
> (i) Briefly explain the concept ....
>
> (ii) Choose the two situations which are <u>most</u> representative of the concept of economic space, and the two which are <u>least</u> representative
>
> (a) Space occupied by an industrial site
>
> (b) Area worthy of resource extraction
>
> (c) Area defined by economic exchange
>
> (d) A network of communications
>
> (e) Area occupied by public gardens
>
> (f) The site of a commercial banking company
>
> (iii) Assess the following statement:
>
> Economic space can be expressed as a surface
>
> (iv) Briefly explain your answer ....

Four types of questions are asked on the concept of economic space, as it is the terminal concept being tested in the hierarchy, the four questions ensuring greater information is obtained from the student. The use of different types of questions tests the students in slightly different ways.

The request for an explanation of a concept was dealt with in relation to Question 1, the reasons given being applicable to Question 4. Open-ended questions give students more freedom than a multiple choice, and the sub-concepts mentioned in the explanation by the student indicate what are thought to be concepts comprising economic space. Such subconcepts mentioned will be used to check against the postulated hierarchy, and also used in an attempt to derive possible origins of misunderstandings.

The need to give two of the 'most representative' and 'least representative' reduces the possibility of guessing producing the correct answers. Further the ability to select examples and non-examples of a concept requires a level of formal thinking. Hence the stipulations attempt to elicit the level of understanding of the concept as pre-formal or formal.

The fourth question attempts to check answers to Question 3. Question 3 tests the ability to draw an analogy between physical and abstract situations, which requires formal thinking. In order to reduce the unknown number who guess question 4 requests an explanation, and attempts to elicit the student's understanding of economic space to the extent of being able to accept or reject an analogy. Answers to the questions on the concept of economic space will be related to answers in Questions 1 and 2A, with subsequent reference to the hierarchy postulated at the outset. Since social space is suggested as having a lateral relationship with that of economic space, although embodying other concepts not tested or mentioned in the hierarchy, a question on social space was included since otherwise untapped information may not be yielded.

v) Question 2Ci - Social space

Question 2C

Using the above diagram (model landscape):

(i) Assess the following statement:

Just as physical space between places A & B can be measured in terms of physical distance ... so the social space between A & B can be measured in terms of social interaction between the places ..

Briefly explain your answer ....

Only the one question was asked on the concept of social space, since the terminal concept being examined closely was that of economic space. Due to there being one question only, the students were asked to make reference to the model landscape which would be familiar to the students having referred to it for previous questions. In this way, students were able to make use of the model landscape as a type of visual aid, with examples of aspects needed for the answer being visually evident should the students understand the concept fully. Asking the question in such a way, was designed to eliminate as much ambiguity or misunderstanding from the similar question asked later regarding economic space.

Once again, the open ended question elicits subconcepts regarded as important by the student. One term anticipated as being used by students throughout the questionnaire, was 'geographic space'. In order to overcome any possible lack of clarity as to what the students understood by the term, was one reason a short question was included in the questionnaire.

vi) Section I Question 2Cii - Geographic space

Question 2Cii

List what you think would constitute the attributes of geographic space in the above diagram ....

Apart from serving to indicate what students understand by the concept of geographic space, should it be used in answers to questions, the answers should suggest whether students list physical or geomorphological attributes only, and not economic and social aspects. Further, answers to Question 3 on the concept of space are compared to attributes listed for geographic space in order to identify any trends or links between answers.

v) Section I Question 3 - Space

Question 3
For the concept of space:
i) Briefly explain the concept ....
ii) Carefully assess the following statements ...
a) - n) ....
iii) How many dimensions can space have?
iv) Name some of these dimensions

Introducing questions on the concept of space is an attempt to elicit what is brought to mind when the students are confronted by the concept 'space' as opposed to specified forms of space such as social space. The concept of space is examined in as much detail as is the hierarchy's terminal concept of economic space, since concepts of space are the underlying factors being examined in the geographical context. No adjective is added to 'space', since the aim of Question 3 was to elicit the students' response to the term and concept 'space'.

The first request is for a brief explanation, which is then compared with answers to the remaining questions, as well as with previous questions. The second part of the question requires fourteen statements to be assessed. The pilot study indicated that students did not get restless with the large number of statements, but rather found the statements "interesting" and "challenging".

The series of statements to be assessed were formulated on the basis of geographical literature indicating the range of interpretations evident in research publications, and texts designed specifically for instruction purposes for University students. Reference was made to types of space in the discussion of concepts of space in geography. Relationships between assessments of the statements and previous questions are examined.

Finally, the third and fourth sections of the question on space refer to dimensions of space. Responses to these sections will further elicit the students' understanding of space, and suggest how each student would measure and map space.

The above discussion of the questionnaire deals with the selection of questions which explicitly aim to test geographical concepts in the hierarchy. The remaining questions, (namely Section I : 2B, 2Ciii; and Section II : 1-5) are concerned with examining the students' levels of intellectual development in performing different tasks. Modelled on empirically-tested Piagetian tasks, the remaining questions serve as well-accepted standards which suggest the levels of conceptual development of students.

e) Questions concerning levels of intellectual development

Since the development of reasoning abilities is gradual, a student may exhibit one level of thinking in a task, and yet another level of thinking in another task (Fuller, Karplus and Lawson, 1977). A single task or question would therefore give little indication of the extent to which a student has undergone transition of cognitive ability. The administration of the tasks designed to test operational abilities of students as demonstrated in their understanding of geography concepts would yield insufficient results on which to draw conclusions. Apart from the pilot study, the questions on geography concepts have not been used previously for examining operational thinking. The use of widely-accepted tests which have revealed empirical regularities in the testing of reasoning abilities were included in the questionnaire as a measuring rod for the effectiveness of the tasks on geography concepts. The Piagetian based tasks were selected for their relevance to the geography concepts being tested - namely the theme of space. Not clearly employing geography concepts, the Piagetian tasks would be unfamiliar to most students.

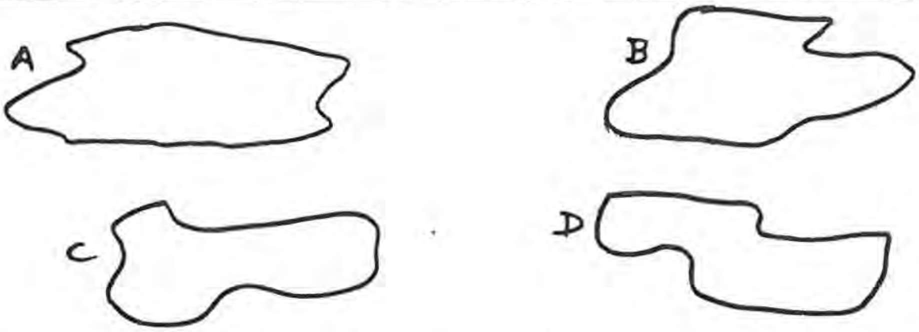
The advantage of unfamiliar content and context lies in that within the context of the students' own discipline, they may appear to consistently reason at the formal operational level and/or comprehend formal concepts. Karplus and Karplus (1970) advocate that when apparent formal thinking is demonstrated, often the students are only applying memorised formulas, words or phrases. Therefore including Piagetian-based tasks in the questionnaire, offers tasks in unfamiliar contexts outside direct discipline experience, reducing the possibility of memorised responses.

Seven Piagetian-based tasks were introduced in the questionnaire. No single task is sufficient to examine cognitive levels of students due to the fallability of question formats; the possibility of error in analysis of any single task; the narrowness of what the task actually tests; and the student being given only one opportunity to demonstrate his ability. The number of tasks were selected to make up approximately half the questionnaire. The questions will be discussed in the order in which they appear in the questionnaire.

i) Question 2B - Commuting by car. Based on activities in space, the question consists of a series of clues and questions. The question is designed along the lines of what is known as the 'Islands Puzzle'. The design of the original puzzle was changed from the setting of four islands to that of four towns, to make use of the model landscape already introduced into the test. Below is the original islands puzzle from Karplus and Karplus (1970), for comparison with Question 2B, which was an adaptation of the puzzle for the questionnaire.

The islands puzzle is not taken directly from Piaget's tasks. The puzzle was designed by Karplus and Karplus (1970) to elicit responses which display the respondent's cognitive abilities as outlined by Piaget. The major advantage of the puzzle as a test for formal thinking is that the differences in students' reasoning processes and hence cognitive abilities are clearly revealed (Fuller, Karplus and Lawson, 1977). Although there is some debate as to which of Piaget's psychological parameters are tested in the puzzle, it is agreed that it tests the prevalence of formal operations (Blake, Lawson and Nordland, 1976; Phillips, 1977; lawson, 1978). In its objective, then, the islands puzzle is a Piagetian-type task.

The islands puzzle. (Fuller, Karplus and Lawson, 1977, p.26)



There are four islands in the ocean, Islands A, B, C and D. People have been travelling to these islands by boat for many years, but recently an airline started in business.
Carefully read the clues about possible plane trips at present. The trips may be direct or include stops and plane changes between the islands.

First clue: People can go by plane between Islands C & D

Second clue: People can not go by plane between Islands A & B. Use these clues to answer Question 1. Do not read the next clue yet.

1. Can people go by plane between Islands B & D?
   Yes ..... No ..... Can't tell from the two clues ....
   Please explain your answer ....

Third clue: (Do not change your answer to Question 1 now!)
People can go by plane between islands B & D. Use all three clues to answer Questions 2 and 3.

2. Can people go by plane between Islands B & C?
   Yes ..... No ..... Can't tell from the three clues ......
   Please explain your answer.

3. Can people go by plane between Islands A & C?
   Yes ..... No ..... Can't tell from the three clues ......
   Please explain your answer.

In design the puzzle has similarities with Piaget's original tasks. The design of the puzzle requires a selection of three possible answers for each question accompanied by a brief explanation. An explanation is seen as vital by Piaget for exposing the reasoning the individual used in the choice of answer. Karplus and Karplus (1970) did not include interviews as part of the research design, but in this study individual interviews with the respondents enabled exploration of the reasoning used and hence the operational ability to be displayed. As with Piaget's tasks, the responses to the puzzle are examined and categorised according to operational abilities.

The puzzle was not included in the pilot study. The other Piagetian tasks have been adapted for the questionnaire from the form in which they have been administered orally, and required a pilot survey to check the written form of the tasks. The puzzle, however, has demonstrated empirical regularities in written form in previous research eliciting valid written responses. Therefore the puzzle can be administered with a degree of confidence that problems involving semantics, syntax, number of clues, and presentation would have been detected and corrected. As can be seen by comparing the original islands puzzle with the puzzle used for the students tested, no change in format was made, only a change in the setting from islands to towns.

ii) Section I Question 2Ciii - Scale and ratio

> Question 2Ciii
> Scale is the ratio between map distance and the actual ground distance that the map represents. If the scale of the above model landscape is 1:100 000, what would be the scale if the landscape was reproduced to half its present size?

Ratio and proportional reasoning are characteristics of formal operational ability. Wollman and Karplus (1974) found that only twenty percent of high school students tested consistently demonstrated the ability to use proportional reasoning.

Map scales are amongst the first exercises first year geography students are subjected to at Rhodes University. All students to whom the questionnaire was administered have had some instruction on map scales. In the light of theoretical background cited in an earlier chapter, few first year university students seem capable of formal thinking, yet map scales, which involve proportional reasoning, are a basic and necessary concept for the use of maps and mapping. On this basis it was considered pertinent to include a ratio task in the questionnaire.

iii) Section II Question 1 - Subdivision of a line

> Question 1. ________________________________
>
> With reference to the straight line drawn above:
>
> i) Imagine a line half its length.
>
> ii) Imagine a line half the length of i).
>
> iii) If you were to carry on cutting up this line continually, you would eventually be left with:
>
> a) Nothing at all
>
> b) A small line
>
> c) A point with the shape of a line
>
> d) A point without the shape of a line
>
> e) None of the above.

Section II states in an introductory sentence that the concern in this section is with general concepts of space. The students were informed that they need not attempt to integrate these questions into a geographical context. Question 1 involves subdivision beyond the extent of visual comprehension, and requires the student to use imagination and think in hypothetical terms - a characteristic of formal thinking. The question also concerns the shape of the final segment as understood by the student. The central concept being tested is that of continuity or infinity - a formal concept of topological space (Figure 3).

The multiple choice question - stem and alternatives - were based on transcripts from tapes, by Piaget and Inhelder (1967). The wording of the stem aimed toward enabling the student to use imagination rather than be restricted to what could be drawn on the paper. This was attempted by the use of the word 'imagine' as opposed to 'draw'. The alternatives offered were selected from Piaget's and Inhelder's (1967) results and classification of responses. Tables in the analysis indicate the Piagetian classification of alternatives offered. During the analysis of results, the alternatives will be discussed at greater length.

iv) Section II Question 2 - Shrinking triangle

Question 2 

If the triangle above was continually reduced or shrunk, you would eventually be left with:

a) Nothing at all

b) A point the shape of the triangle

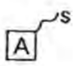
c) A very small line

d) A point with no particular shape

e) A point with a slight peak.

The triangle problem is essentially the same as the subdivision of a line in Question 1. It acts as a check for consistency in ability to demonstrate an understanding of continuity and infinity. Tables in the analysis list the alternatives and the Piagetian stages which are exemplified by answers chosen. As with the subdivision, the problem requires formal thinking.

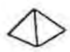
v) Section II Question 3 - Squares of cardboard

Question 3 

'A' above shows a piece of cardboard with an attached string 's'. If 'A' was held by the string and spun by twisting 's', what would the shape described by the perimeter of the cardboard be?

a) Cube 

b) Cube tilted 45° 

c) 3-sided pyramid 

d) 

e) 

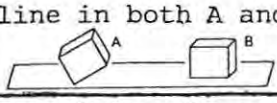
A correct answer to this problem exhibits an advanced level of transition between projective and Euclidian space. The alternatives are scored only with three values since the task does not examine specifically formal thinking and transition between concrete and formal is sufficient.

vi) Section II Question 4 - Water tank

Question 4

The diagram below shows a closed water tank, one fourth filled with water

Complete the diagrams below by drawing in the water line in both A and B.



Understanding and supplying the correct frame of reference is tested in the water tank question. Pre-operational to concrete abilities are tested. A correct answer can be arrived at without formal thinking (Phillips, 1977; Piaget and Inhelder, 1967). Tables in the analysis describe the three responses and the associated scores.

vii) Section II Question 5 - Model landscape sketch

Question 5

Refer back to the sketch of the model landscape in Section I. The sketch is viewed from the south. In the space below, redraw this model landscape as it would be viewed from the north.

Redrawing an object from an imagined point of view involves capabilities of projective space. This type of problem should not be foreign to an undergraduate geography student, and Hart and Moore (1973) suggest projective spatial ability is essential for aerial photograph interpretation. The task is a useful one in that on analysis, the sketches can demonstrate abilities ranging from stage IIB through to stage IV or formal thinking.

Each question has been studied in accordance with its aims and rationale for inclusion in the study. The variety of question-types is evident, and is necessary in order to maintain the student's interest, and to elicit the range of student abilities required. It remains to analyse the responses to the questionnaire. In doing so, further detail regarding the questions will arise.

D. OVERVIEW

The methodology adopted in an analysis of geography concepts is crucial as part of a new area of research. Concepts of space were selected for the study, since space is a central concept in human geography. Much of human geography cannot be referred to as exact science. Concept analyses in other disciplines have dealt with exact science concepts, where mastery of the concept is evident in the ability to understand and use formulae. There is far less clarity in determining whether a student understands a non-exact science concept. The methodology is therefore a major focus of the study, warranting the present chapter being devoted to aspects of the methodology.

The construction of the hierarchy, the interview, and the validation technique employed form an important part of the methodology and were described in detail. The structure and form comprising the questionnaire is exposed in a section of its own. The questionnaire design is important, since the responses to the questionnaire are the data used for the analyses. The responses are required for the test for validation of the hierarchy, and in the analysis both of levels of understanding of the concepts of space, and of levels of conceptual ability.

CHAPTER FIVE

APPLICATION OF CONCEPT ANALYSIS TO THE SELECTED CONCEPTS OF SPACE

The premise that comprehension of any concept is dependent on the understanding of prerequisite concepts was proposed by Gagné (1962). Whilst Gagné's work reveals the need for learning hierarchies to be postulated and tested empirically for validation (Linke, 1975), Piaget's work emphasises the need to consider the level of understanding required for each concept. The present chapter is composed of both objective and subjective analyses of the proposed concept hierarchy and of students' conceptual abilities.

The first section subjects the hierarchy of concepts of space to a test of validity, on the basis of which the hypotheses are either accepted or rejected. Qualitative differences in students' performances are discussed where the quantitative validation technique is insufficient to highlight particular hierarchical connections between concepts as exhibited by students' responses. Section B is the analysis of students' performance on the Piagetian-type tasks which establishes the range of conceptual abilities amongst the students. Section C examines students' responses to the questions on concepts of space which is apart from the hierarchy analysis, but to which reference is made. The focus is therefore on misunderstandings expressed. Finally, in the overview the analysis is reviewed as a whole.

A. ANALYSIS OF THE PROPOSED HIERARCHY FOR SELECTED CONCEPTS OF SPACE IN GEOGRAPHY

The technique of White and Clark (1973) is applied to seven pairs of concepts in the hierarchy. The pairs which were selected are concepts which are adjacent in the hierarchy in terms of one concept being higher in relation to the other. Each pair is tested for validity of hierarchical connections and the hypotheses are tested for each pair. Since the test for validity is based on quantitative measures, it becomes evident that the qualitative differences in students' responses can reveal valuable insights to patterns of thinking or misunderstandings. A qualitative review of the hierarchy is followed by a discussion of the validation technique which concludes the hierachical analysis.

1. Tests for validity of hierarchical connections.

Relationships between concept pairs will now be focussed upon. Beginning with the lower pairs in the hierarchy, the selected concept pairs are tested, through to the terminal concept of economic space and its pair. Only one of the concepts of space from the Piagetian-type tasks are included in the analysis: the concept of infinity. All other concepts dealt with in the hierarchical analysis are specifically geography concepts. The concept of infinity is included because of its strategic position in the hierarchy amidst the geography concepts being tested for their connection with adjacent concepts. In order to establish whether a hierarchical relationship does exist between pairs of concepts, the hypothesis is set for each pair. The hypothesis is that those with skill II, are totally included among those with skill I (White and Clark, 1973) where skill II is the higher concept in the hierarchy, and skill I a postulated prerequisite or adjacent concept. The first pair to be considered is relative space/relative distance, and interaction, for which the computations will be shown in detail, and given in summary for the rest of the analysis.

a) Relative space/relative distance and interaction.

Skill II: Relative space/relative distance

		0	1	2	Total
Skill I	2	2	4	3	9
Interaction	1	4	6	7	17
	0	5	5	2	12
Total		11	15	12	38

Table 3: Observed numbers of students answering correctly 0, 1 or 2 questions for either concept: relative space/relative distance and interaction.

The observed marginal totals will be referred to as a-f. Proportion and probability parameters are derived from the marginal totals. The proportions (P) and probabilities (θ) express the probability that a randomly selected student from the sample answered correctly zero, one or two questions for either skill. The observed marginal totals are as follows:-

a=9 b=17 c=12 d=12 e=15 f=11

The unknown parameters Θb and Θc are assumed to be 1 and 0 respectively and the assumptions are the most conservative possible (White and Clark, 1973).

Θa and Θd are derived as follows:

$$\Theta a = \frac{2a}{2a+b} = \frac{2 \times 9}{2 \times 9 \times 17} = 0{,}514$$

$$\Theta d = \frac{e}{e+2f} = \frac{15}{15+2+11} = 0{,}405$$

$$Q = \frac{(2a+b)^2}{4aN} = \frac{(18+17)^2}{4x9x38} = 0{,}896$$

$$R = 1-\frac{(e+2b)^2}{4fN} = 1-\frac{(15+22)^2}{4x11x38} = 0{,}181$$

Under H: PII = 0 (that those with skill II are totally included in skill I):

$$P_1 = Q - R = o{,}714$$

$$P_o = 1 - Q = 0{,}105$$

$$P_B = R = 0{,}181$$

The estimate of the probability that a member of the sample will be in the 0-2 cell of Table 3 is found by substituting the above estimates in the equation for P_{o2} given previously in Chapter Four, Section B3:

$$P_{o2}=0{,}105x1^2x(0{,}4054)^2+0{,}7143x(1-0{,}514)^2x(0{,}405)^2+0{,}181(1-0{,}514)^2x1=0{,}0876$$

$$P(f_{o2}=0)=1-0{,}088)^{38} = 0{,}031$$

$$P(f_{o2}=1)=38x0{,}088x(1-0{,}088)^{37} = 0{,}112$$

$$P(f_{o2}=2)=\frac{38x37}{2} x(0{,}088)^2(1-0{,}088)^{38}= 0{,}199$$

$$P(f_{o2}\geqslant 2)=1-0{,}031-0{,}112 = 0{,}857$$

Since the cumulative probability is 0,857 ($>$0,05), the hypothesis that those with skill II are totally included among those with skill I cannot be rejected at the 5% level. This indicates that for the students tested, if it were not for chance errors or errors of measurement, all students who understood the concept of relative space/relative distance also understood the concept of interaction. Hence, on the basis of the validation technique, it can be stated that there is not an invalid hierarchical connection between relative space/ relative distance and interaction.

b) Relative space/relative distance and accessibility.

Skill II: Relative space/relative distance

Skill I: Accessibility		0	1	2	Total
	2	2	4	12	18
	1	4	9	0	13
	0	5	2	0	7
Total		11	15	12	38

Table 4: Observed numbers of students answering 0, 1 or 2 questions correctly for either concept: relative space/ relative distance and accessibility.

The number of observed students in the 0-2 cell in Table 4 is zero. Since zero is the smallest possible observed value under the hypothesis P_{II} =0, the validation technique does not allow for the hypothesis to be rejected, since an accurate hierarchical connection is denoted by zero students observed in 0-2 cell (White, 1973). Hence the hierarchical connection between relative space/relative distance and accessibility does not appear to be invalid.

c) Infinity and accessibility.

Skill II : Infinity

Skill II: Accessibility		0	1	2	Total
	2	8	10	0	18
	1	7	7	0	14
	0	2	2	2	6
Total		17	19	2	38

Table 5: Observed numbers of students answering correctly, 0, 1 or 2 questions on either concept: infinity and accessibility.

a=18 b=14 c=6 d=2 e=19 f=17

θa = 0,720

$\theta d = 0{,}359$

$Q = 0{,}914$

$R = 0{,}855$

Under H : $P_{II} = 0$

$P_1 = 0{,}059$

$P_o = 0{,}086$

$P_B = 0{,}855$

$P_{o2} = 0{,}079$

$P(f_{o2}=0) = 0{,}044$

$P(f_{o2}=1) = 0{,}143$

$P(f_{o2}=2) = 0{,}227$

$P(f_{o2} \geqslant 2) = 0{,}813$

Since the cumulative probability is 0,813 (>0,05) the hypothesis that those with skill II are totally included amongst those with skill I cannot be rejected at 5% level. The technique thus indicates that there is not an invalid hierarchical connection between infinity and accessibility.

d) Infinity and interaction.

Skill II : Infinity

		0	1	2	Total
Skill I : Interaction	2	2	4	3	9
	1	5	4	9	18
	0	3	5	3	11
Total		10	13	15	38

Table 6: Observed numbers of students answering correctly 0, 1 or 2 questions on either concept : infinity and interaction.

a=9 b=18 c=11 d=15 e=13 f=10

$\theta a = 0{,}500$

$\theta d = 0{,}394$

$Q = 0,947$

$P = 0,652$

Under $H : P_{II} = 0$

$P_1 = 0,295$

$P_o = 0,053$

$P_B = 0,652$

$P_{o2} = 0,183$

$P(f_{o2} = 0) = 0,001$

$P(f_{o2} = 1) = 0,004$

$P(f_{o2} = 2) = 0,016$

$P(f_{o2} = 3) = 0,044$

$P(f_{o2} \geqslant 3) = 1-0,065$
$= 0,935$

Since the cumulative probability is 0,935 ($>$ 0,05), the hypothesis that those with skill II are totally included amongst those with skill I cannot be rejected at the 5% level. It is apparent then, that there is a valid hierarchical connection between infinity and interaction.

e) Distance decay and infinity.

Skill II : Distance decay

		0	1	2	Total
Skill I : Infinity	2	7	8	0	15
	1	6	7	0	13
	0	4	4	2	10
	Total	17	19	2	38

Table 7: Observed numbers of students answering correctly 0, 1 or 2 questions on either concept: distance decay and infinity.

a=15 b=13 c=10 d=2 e=19 f=17

$\theta a = 0,698$

$\theta d = 0,359$

$Q = 0,811$

$R = 0,216$

Under $H : P_{II} = 0$

$P_1 = 0,595$

$P_o = 0,189$

$P_B = 0,216$

$P_{o2} = 0,052$

$P(f_{o2} = 0) = 0,126$

$P(f_{o2} = 1) = 0,268$

$P(f_{o2} = 2) = 0,277$

$P(f_{o2} \geqslant 2) = 0,329$

The cumulative probability is 0,329 ($> 0,05$). Therefore the hypothesis that those with skill II are totally included amongst those with skill I cannot be rejected at the 5% level. This indicates that the hierarchical relationship between distance decay and infinity is not valid.

f) Distance decay and relative space/relative distance.

Skill II : Distance decay

		0	1	2	Total
Skill I :	2	2	7	2	11
Relative space/	1	10	6	0	16
relative distance	0	5	6	0	11
	Total	17	19	2	38

Table 8 : Observed numbers of students answering correctly 0, 1 or 2 questions for either concept : distance decay and relative space/relative distance.

Since the observed number of students in cell 0-2 is zero, the hierarchical connection between distance decay and relative space/relative distance would not appear to be invalid.

g) Economic space and distance decay.

Skill II : Economic space

Skill I : Distance decay		0	1	2	Total
	2	1	2	0	3
	1	12	5	3	20
	0	10	5	0	15
	Total	23	12	3	38

Table 9 : Observed numbers of students answering correctly 1, 0 or 2 questions for either concept : economic space and distance decay.

Again, with the observed number of students in cell 0-2 being zero, it is apparent that there is not an invalid hierarchical connection between the terminal concept of economic space and distance decay at the 5% level.

A summary of the validation of the hierarchy would be premature prior to a qualitative consideration of the hierarchy. An evaluation of the hierarchy and validation techniques will then be discussed.

2. A view of the hierarchy from a qualitative standpoint.

Close observation of students' responses in detail can reveal particular patterns of thinking or a misunderstanding in a concept which is transferred to another concept. Statistical analyses are not able to pick up such trends for individuals. Two cumulative hierarchies are constructed, giving examples of typical responses only on the concepts tested for valid hierarchical relatedness. Prior to the introduction of the two hierarchies, a hierarchy of total numbers of students mastering the concepts at concrete and formal levels is given. The hierarchy shows the marked diminishing of numbers of students mastering the concept from the lower to the higher concepts (Fig. 5). The hierarchy (Fig. 5) has been split towards the base, and two figures are given as totals of students' responses. The numbers in the foreground are totals of students understanding the concept at a concrete level. Those in the background, as well as those continuing in the upper half of the hierarchy,

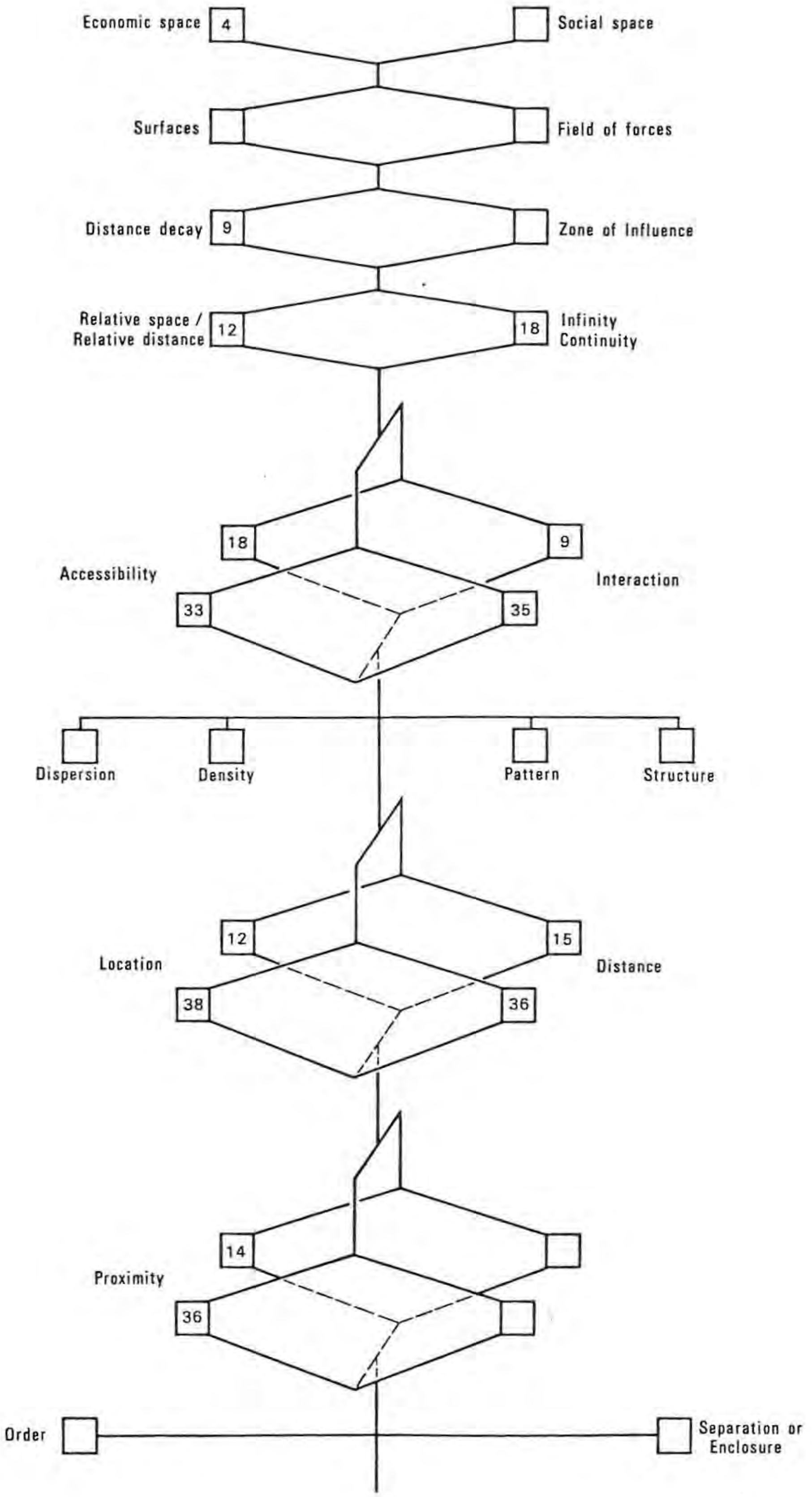


Figure 5: Numbers of students mastering the concepts tested for hierarchical connection at concrete and formal levels, represented by numbers in the foreground, and in the background respectively.

are totals of students understanding the concepts at a formal level. On the lower half of the hierarchy, the totals for concrete understanding include all those who have understood the concept at a formal level. The inclusion is made since the former is necessary for the latter. Only those concepts tested in the study are included in the figure.

Formal responses vary radically from the concrete responses. For example with the concept of location there is both a concrete concept and a formal concept. Hence in the analysis, two concepts of distance were being tested. The split in the lower half of the hierarchy illustrates the duality of the concepts. Concepts in the upper half are not dual, there being no concrete concept of any of them, and hence necessitating a formal level of understanding. Particular responses demonstrate the different levels of comprehension of students. The responses are summarised in Figs. 6 and 7.

Referring to Fig. 6, possible relatedness between concepts may be recognised. For example, the students typically did not demonstrate a formal understanding of the concept of location. Location is seen in terms of physical location. This viewpoint may be one of the causes for accessibility being understood only in terms of relief and the physical landscape, rather than cost and time for example. On the concept of space, the understanding evoked by the term generally fell into the category of two or three dimensions. Neither is the possibility of time or socio-economic factors as dimensions considered, nor is the possibility of more than one space considered. Continuing up the hierarchy, geographic space cannot be fully understood as including aspects other than the physical, due to prior limited understandings to the visible and concrete. Thus one example has been quoted, and is a simplified generalisation since not all students who exhibited formal thinking on zero, one or two Piagetian-type tasks demonstrated these conceptions. Some students' responses were inconsistent in that they gave a concrete response to some lower concept and formal response to a higher level concept. What the hierarchy does show in Fig. 6 are typical responses.

The tracing of individual students on such a hierarchy is invaluable for establishing the reasons for and origins of their misunderstandings.
A similar simplified pattern may be traced amongst the students exhibiting formal thinking on three, four, or five tasks (Fig. 7). Following the asterisks in Fig. 7 which begin at the responses to accessibility, the concept

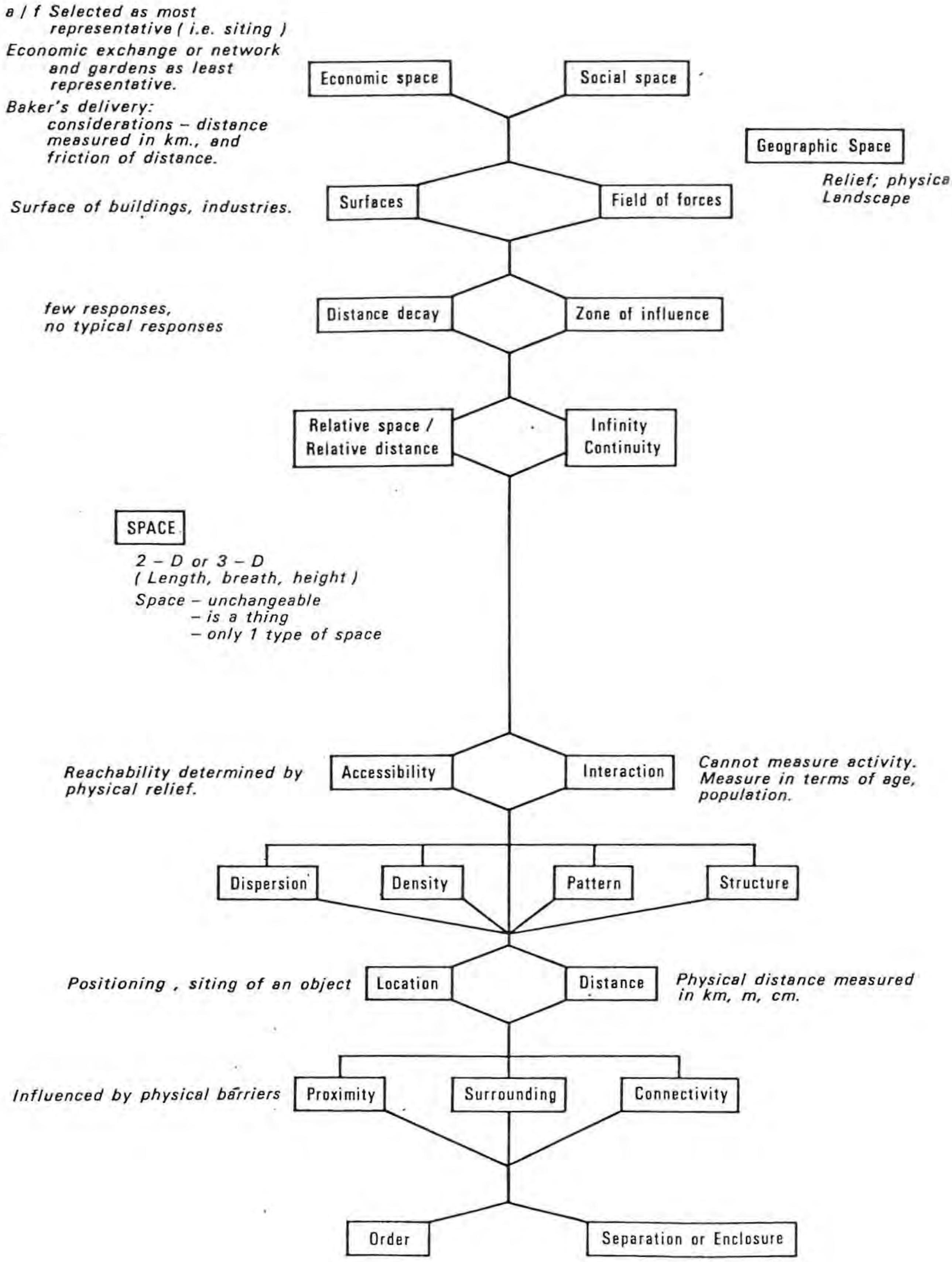


Figure 6: An annotated hierarchy of typical responses by students exhibiting formal thinking on 0, 1 or 2 Piagetian-type tasks.

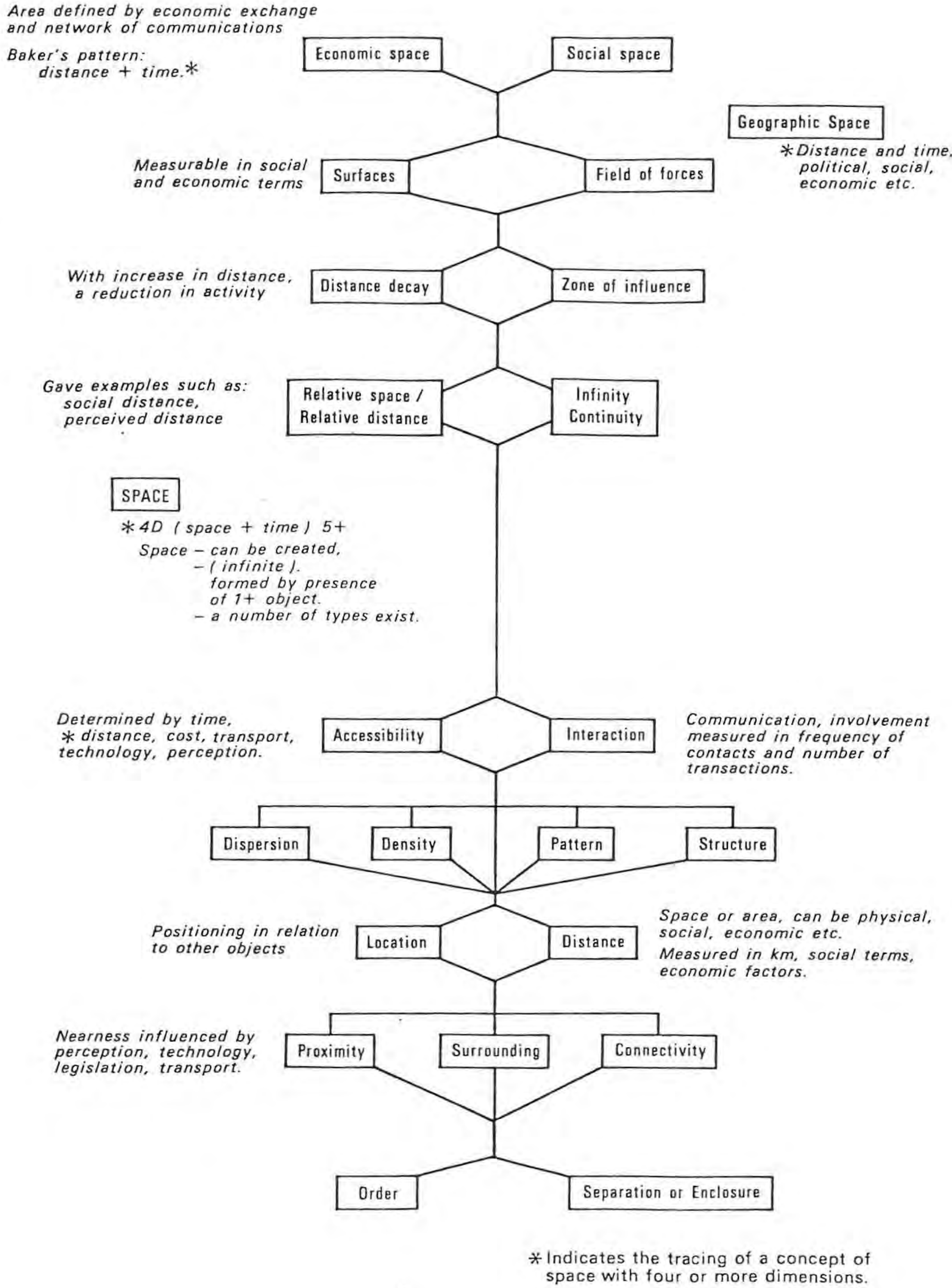


Figure 7: An annotated hierarchy of typical responses by students exhibiting formal thinking on 3, 4 or 5 Piagetian-type tasks.

is understood in terms of visible and abstract aspects such as time and cost. On the concept of space, more than three dimensions are considered and include the abstract such as time. Toward the top of the hierarchy, both geographic and economic space are understood in the abstract or formal terms.

The discussions of the hierarchies subjectively has been brief. The aim of the discussion firstly was to highlight certain hierarchical relatedness between concepts by a few students. The statistical analysis was unable to reveal individual patterns of thinking. Secondly, the aim was to point out the need for an increased awareness of a technique available for the exploration of sources of misunderstandings. The hierarchy will now be considered on the basis of the statistical analysis and the subjective appraisal.

3. Discussion of the analyses of the hierarchy

Both the statistical validation test and the subjective analysis indicated that valid hierarchical connections between concepts did exist. The statistical test concerns the number of students who answer correctly both questions for the higher concept, but incorrectly on both questions for the lower concept. The subjective analysis involved focussing on individual patterns of thought. Both techniques revealed results worthy of discussion in relation to the two techniques. The first to be considered is the statistical test.

The postulated hierarchical connections between all seven pairs of concepts tested in the hierarchy were revealed by the technique to be strong enough not to reject the hypotheses. For each pair, it was postulated that skill I was essential for the understanding of skill II. Although there is no clear evidence to the contrary, it would seem unlikely as first postulations of their kind that all tested connections in the hierarchy would not be invalid. The technique does not provide for a statement of validity to be made, only invalidity, yet further research is needed to establish the precise reasons for the results of the validation test. Possible reasons lie in the three fields of: the questionnaire and scoring; the testing of non-exact science concepts; and the validation test itself.

In the first field, if the assessment of students' responses and their categorisation is incorrect, or the questions posed do not reliably test the concepts set, the observed frequencies in Tables 3-9 do not reflect students' abilities. Should this be the case, the hierarchy would not have been tested for validity. However, such a case is extreme, and it is likely that elements of error exist in both the questions and scoring technique. Although the questionnaire was subjected to scrutiny by three geography experts and a pilot study, further exploration is needed into the construction of questions which do test reliably vital concepts in geography.

The test may not apply as well to non-exact science concepts as it does to computational skills for which it was designed where the student clearly either obtains the correct answer or he does not. This illustrates a difference between exact and non-exact science concepts. In the testing of the concepts in this study, responses were spread over a spectrum of increasing understanding. Although a decision was made for each question as to what would constitute adequate understanding of a concept and hence be given a score of one, the decision was subjective. The opportunity for error is therefore great, particularly when the definitions of the concepts of space tested are not clear in the literature, and hence possible differences in mark allocation would exist between geographers. Such a situation itself calls for further research.

The validation test is still undergoing improvement in the area of greater accuracy of techniques in allowing for errors of measurement (Hofmann, 1977). For example, White and Clark (1973) show that it is not a powerful test. In the present study the hypothesis was not rejected for a range of zero to three students in cell 0-2. Hence there may be room for increasing the test's sensitivity. Also, since an observed number of students of zero in 0-2 cell denotes an accurate hierarchical relationship, the test needs to be developed in order that the role of chance and error of measurement in producing zero can be established. Further, certain assumptions are limiting. The assumption that chance errors on a set of questions for a concept pair are independent of one another, may not hold for the questionnaire of the present study. The questions were deliberately designed to be closely related to other questions so as to trace patterns of thinking and possible origins of misunderstandings. Therefore chance errors on related questions would not necessarily be independent. The second is to assume that "...the skills have been so closely defined that the two questions for skill I (and skill II) would both be answered correctly or both incorrectly by all subjects if it were not for errors of measurement" (White and Clark, 1973, p.78). In examining geography concepts which do not entail formulae, certain misunderstandings of concepts result in a correct answer to one question only, thereby reflecting a degree of understanding. However, an incorrect answer to the other question on the same concept, indicates inadequate understanding if it is assumed that correct answers to both questions indicate adequate understanding. A final assumption is that the sample is a random sample of a population. For this case study, the sample comprised all students in the second year geography class at Rhodes University. However it is not unreasonable to suggest that the sample is representative of the population of second year university geography students in South Africa. This can be argued since teaching methods and text book recommendations in the geography department at Rhodes University are not dissimilar to other geography departments; and there is no selection of students except that they pass first year geography. Finally, the statistical test relies on initial subjective judgements such as what constitutes indications of adequate understanding.

The validation test, then, although having overcome many problems found in other techniques, may need to be modified specifically for testing concept hierarchies where a range of misunderstanding exists. A greater clarification of what would constitute a correct answer to polarise students' responses in an attempt to solve the problem of degrees of understanding is out of place in concept analysis. One aim of paramount importance in concept analysis is ideally that of questions designed to explore all areas of the students' understanding and to display patterns of correct and incorrect thinking. It becomes apparent that there is a research need for a modified hierarchy validation technique which could take the above into consideration. In the qualitative analysis of the hierarchy, the main limitation is that time is prohibitive. Although there is room for suggestion and influencing students' responses in interviews, care must be taken to be aware of such possibilities; and students need to be encouraged to think aloud and speak honestly, which should help the researcher to follow the student's thinking. Much value lies in this method of tracing an individual student's patterns of thinking. The researcher's tentative hypotheses as to why the student has made the mistakes he has can be checked on interviewing the student. Reasoning patterns of the particular student and the essential individuality of learning are not lost as in generalisations made for the class, and any necessary remedial action required for the particular student can be identified. The quatitative analysis serves to demonstrate the possibility of an individual approach to hierarchies.

Interestingly, the few students used to illustrate the qualitative viewpoint of the hierarchy, as well as the generalised annotated hierarchies, only reinforced the possibility of valid hierarchical connections as indicated by White and Clark's (1973) test. On the strength of both methods of analyses of the hierarchy, within the constraints of each test it may be accepted that the hierarchy comprised of the seven pairs of concepts is not invalid. However, the hierarchy needs to undergo further research in terms of different samples of students and different pairs of questions asked on each concept before a statement of validity about the hierarchy could be approached. Required also, is research into methods of assessment of students' ranges of performance, and toward the modification of hierarchy validation tests for the non-exact sciences. However, concept hierarchies cannot be considered in isolation from students' conceptual abilities. Reasons for students' misunderstandings of the concepts tested could include that the students do not have the conceptual ability required for the concept. The following section examines this possibility.

B. ANALYSIS OF PERFORMANCE ON PIAGETIAN-TYPE TASKS

Responses to each task will be discussed in turn. As mentioned earlier in the explanation of concrete and formal thinking, it is difficult to classify a student as a concrete or a formal thinker. Students exhibit different abilities on different tasks. Hence the responses, rather than the students, are categorised as belonging to a stage and the means of categorisation is explained for each task. Finally, in the overview, all responses are discussed as a whole, followed by a consideration of each of the hypotheses.

In accordance with the hypotheses that there will be students unable to exhibit formal thinking in the tasks, the students' responses are categorised as formal or pre-formal. The broad categories are: Stage II (pre-operational), Stage III (concrete), and Stage IV (formal). Since the development of thinking is a continuous process rather than a series of steps, students may exhibit thinking which is transitional between two stages, or which is not far developed within a stage. In anticipation of such responses, substages were used where the array of abilities within a task were clearly displayed. Abilities were categorised according to Piaget's specifications of abilities, the substages being Stage II_A (early Stage II thinking), II_B (late Stage II thinking), III_A and III_B. Research into formal thinking - Stage IV - has not been sufficiently focussed to be able to specify possible substages. Responses which were transitional between the broader categories of for example II and III, would belong to either IIB or IIIA. In some cases substages were not used when the task served only to elicit whether a student was capable of certain abilities, such as the ratio task, rather than a spectrum of abilities such as the infinity task. The tasks covered aspects of the three main types of space: topological, projective, and Euclidean (Piaget and Inhelder, 1956).

A brief explanation of topological, projective and Euclidean space is of use at this point. Many of the spatial concepts used in geography require the ability to conceptualise Euclidean space. It was with a view to the importance in knowing the students' level of understanding of types of space for teaching geographical concepts that the Piagetian-type tasks were selected. The understanding of Euclidean spatial concepts requires an understanding of both topological and projective space.

An example of topological space is infinity. Infinity has been considered as an extremely important concept in all sciences (Piaget and Inhelder, 1967; Good, 1977). Concepts such as growth, change and concepts of space contain the concept of infinity. The process of subdividing a line indefinitely, according to Piaget and Inhelder (1967), is not conceptualised as possible until the age of eleven or twelve. However, recent studies of mathematics and science elementary text books (Dodwell, 1971; Good, 1977) reveal that the concept of infinity is introduced in the definition of a line as an infinite set of points. Many of the text books are written for those under the age of twelve, and it would appear that the majority of students will not have attained the necessary level of conceptual development. Infinity is one of the more difficult concepts of topological space, and has been included in the questionnaire in Section II, Questions 1 and 2. The student is then asked in the interview to reverse the process by for example, making up the line again. "The process of reducing what is regarded as continuous to a series of (infinite) adjoining points and recreating a continuity on the basis of these points ... is the most advanced type of the operations involved in separating and reuniting enclosed parts ... and is essential to the completion of a qualitative concept of topological space." (Piaget and Inhelder, 1967, p.126). The answers to the questionnaire and interview questions require differing levels of conceptual ability, thereby indicating approximate stages of thinking exhibited by the students on this particular concept of topological space. The understanding of topological space is prerequisite for the understanding of projective space. Question 3 deals with concepts of projective space, and aims to test the ability to mentally picture or develop surfaces by objects producing three dimensional shapes. Although Piaget suggests such an ability is acquired by the age of twelve years, Good (1977) in studying senior college students, found fifty-five percent were unable to correctly rotate the square of cardboard on an imaginary level. The task tests the student's ability to envisage different perspectives and to recognise his viewpoint as one of many. The task is relevant to interpretation of maps and aerial photographs, including stereoscopic vision. The following task also bears relevance on map interpretation.

The transition from projective to Euclidean space involves the mastering of several skills, one of which is the ability to use ratios, and the scale exercise tests this skill. Another is the ability to use a system of reference which the water level task is used to test. On analysis it will become clear that the ability to use a system of reference is prerequisite for map interpretation skills, and aspects of relative positioning or relative space. Under the analysis of the task these implications will be discussed further.

Also dealing with the transition from projective to Euclidean space but later in the stage toward full understanding of Euclidean space is Question 5. The diagrammatic layout illustrates the range of ability amongst students of concrete and formal thinking in concepts of topological, projective and Euclidean space.

Finally, a Piagetian-type task which was designed specifically to assess abstract reasoning ability is used apart from those tasks on concepts of space. The task is a puzzle constructed by Karplus and Karplus (1970) and was adapted for this study. The reasoning required in the task is typical of that needed in the sciences (Fuller, Karplus and Lawson, 1977). The puzzle is then a useful task in addition to those tasks explicitly on concepts of space. Some of the skills tested in the puzzle include making conjectures to aid in answering the questions; holding certain aspects constant (the clues) whilst others are variable; utilising correctly 'if ... then ...' thought patterns; and using hypothesis and deduction in their reasoning. As an aid to analysis, the different qualitative abilities of reasoning displayed are given a mark allocation in order to quantify the results. This introduces the question of the method of analysis.

The analysis of reasoning ability is essentially qualitative in nature. Mark allocation and the weighting of answers as well as the use of the marks in analysis is still an area being explored (Blake, Lawson and Nordland, 1976). For the purpose of the present study, marks are used in the analysis to highlight trends which are evident in a qualitative form. The analysis of the Piagetian-type tasks then is firstly qualitative, with only percentages being referred to, and is followed by a brief quantitative analysis. The interviews are referred to in detail since they clarify how the student's thinking is classified into Piagetian stages. Seemingly unimportant detail, such as the way in which a student interacts in the interview, is vital for a complete assessment of the student's ability. The wide range of Piagetian-type tasks set is due to research which warns against relying on the use of any single task to adequately assess the cognitive ability of students. Although the tasks have been widely accepted as reliable tests, 'noise' such as method of presentation, and familiarity with the questions will always exist (Lawson, Nordland and De Vito, 1975; Rowell and Hoffman, 1975; Lawson and Blake, 1976).

The analysis which now follows deals with the tasks in order as they test first topological, then projective through to Euclidean space and abstract reasoning ability. It will become clear that the Piagetian-type tasks serve two purposes. Firstly, they aid in investigating the general reasoning ability of students. Secondly, since all but one task test the student's understanding of aspects of space, the results can be used to aid in analysis of why students understand as they do the concepts of space used in geography.

1. Question by question analysis of the Piagetian-type tasks.

a) Q1 and 2. Concept of infinity: A line or triangle continuously reduced in size. Eventually you would be left with .....

The principle in both Q1 and Q2 is the same. The table illustrates student's consistency in understanding the common principle. If a student understands the principle involved, he should answer both questions in the same way. For example, by answering d) for Q1, students exhibit an apparent understanding of the concept involved, yet five of these students answered b) for Q2, indicating that in fact they have not fully grasped the concept. The table below displays the responses to the two questions: line and triangle. Each student is positioned in the table matrix, representing his answer to the line and the triangle.

Responses		Piagetian level	Number of Students: Q2 Triangle: IIA a) Nothing at all	IIB c) Small line	IIIA e) Point with slight peak	IIIB b) Point with shape of triangle	IV d) Point with no particular shape
Q1 Line:	a) nothing at all	IIA					1
	b) small line	IIB	1			2	
	e) none of above*	IIIA	1		1	1	4
	c) point shape of line	IIIB				3	1
	d) point without shape of line	IV			3	5	15

Table 10: Students' selected answers to Section II, Questions 1 & 2.

* When asked to elaborate on their answer, <u>all</u> students who selected e), indicated that they were not sure, but thought they would be left with "...something between b) and c)." Such an answer suggests evidence of Piaget's level III thinking.

Explanation of responses to tasks on the concept of infinity: Q1 and Q2.

Q1 Subdivision of straight line (10 cm long)

Q2 Reduction of a triangle 

The discussion below is based on Piaget's explanation of responses encountered in series of interviews conducted by Piaget testing the child's conception of space. The children ranged from pre-operational through to stage IV thinkers. Stages II to IV are relevant to this study, no student having exhibited thinking lower than that of stage II. The classification of responses into stages has been made in accordance with conclusions drawn by Piaget as a result of studies by the Genevan school.

Students' responses were classified on the basis of the results of both questionnaire and interview. The interview served to clarify the student's reasoning behind his answers. Examples of interviews which are given for the purpose of analysis below, show how the interview was conducted. Two additional questions to those on the questionnaire were asked at the interview. Once the student had explained what was left after continual subdivision of the line, the question was asked: "If I joined together a number .... (whatever the student suggested would be left after subdivision - e.g. points, small lines), what would that make?" If the student had not suggested that points would remain in answer to the subdivision question, the interviewer then asked: "If I joined together a series of points, what would be the result?"

Discussion followed both questions, some examples of which will be given below in the explanation of responses. The purpose of the additional interview questions was to check for consistency in the student's thinking, and the extent of his understanding of the concept of infinity. The rationale is further clarified below in the contexts of stage II and more explicitly stage IIIthinking. Each stage will now be discussed in turn.

Stage IIA and IIB

Stage IIA	Line:	nothing at all	Stage IIB	Line:	small line
	Triangle:	nothing at all		Triangle:	small line

During stage IIA and B the student is unable to carry out concrete operations. Students are unable to understand how a line can be divided and subdivided, nor is he able to conceive of a line being made up of a series of smaller lines or points. With reference to the line, the student can only see a series of discontinuous points or small lines, or he can see a single longer line, but can make no connection between the former and the latter. The former, when merged to form one continuous line, are no longer distinctly visible and therefore, to a stage IIA thinker the former no longer exist. Hence, the student thinks along the lines that the long line as given can be subdivided, but one is either left with nothing at all (Stage IIA) or, a slightly more advanced response, with a small line (Stage IIB). Similarly, the triangle is seen as being reduced to nothing at all (Stage IIA), or to a small line (Stage IIB). The student exhibiting Stage IIA or IIB thinking, exhibits no understanding of the concept of infinity (Piaget, 1967). This is illustrated by the following two interviews. The first demonstrates Stage IIA reasoning.

Interviewer: I see you have answered that nothing at all would be left if one continued to subdivide a line.

Student: Yes.

Interviewer: What would there be just before there was nothing at all?

Student: A line.

Interviewer: And if you cut that?

Student: Two halves of the line.

Interviewer: And if you carried on cutting one of the halves?

Student: You'd be left with nothing.

Interviewer: If I joined together a series of small lines, what would that make?

Student: Lots of pieces of lines.

Interviewer: If I joined together a series of points, what would be the result?

Student: I don't know.

Interviewer: If I pushed them together so they were touching?

Student: (Acts confused).

Interviewer: Would it make a line?

Student: No, because it would be bumpy like this (draws something like a caterpillar); and it would have rounded ends.

The second interview below is typical of Stage IIA and B thinking.

Interviewer:	I see you have answered a small line. Now in your imagination, cut that line again.
Student:	You'd still have a line.
Interviewer:	Yes, and cut that?
Student:	Well I guess you'd eventually end up with a minute line.
Interviewer:	And if you carried on cutting that?
Student:	You couldn't because it would no longer be a line.
Interviewer:	In reducing the triangle, you've answered that you'd eventually be left with nothing at all. And just prior to that?
Student:	A triangle.
Interviewer:	What makes up a triangle?
Student:	I don't understand.
Interviewer:	A series of points, or lines, or lots of small triangles?
Student:	A triangle is just made up of itself. If you reduce that, then you're left with nothing at all.

The first student quoted above exhibits Stage IIA thinking and the second exhibits Stages IIA and B. Stage II thinking sees the whole and the part as separate items. A line cannot be conceived of as being made up of a series of points. The student is not able to reverse the process after subdivision. One either joins points, small lines or a line; but once small lines or points are joined, they are no longer visible and merge to become a single entity. To the Stage II thinker, once the parts are not distinctly visible, they no longer exist. The difference between Stage II and Stage III thinking will become clear as responses from Stage III are discussed.

Stage IIIA and IIIB

Stage IIIA	Line:	none of above	Stage IIIB	Line:	point the shape of line
	Triangle:	point with slight peak		Triangle:	point the shape of triangle

Stage IIIA indicates the ability of a student to carry out concrete operations. This means the student thinks in the realm of the tangible and visible, using operations which can combine and which are also reversible.

For example, in terms of the line task, the implication is that the student can combine points and small lines to form a longer line, and can also reverse the process, realising that a series of adjoining points can form a line. However, the student finds difficulty in thinking beyond that which he experiences in perception. Stage IIIA represents students who are limited to the finite. Stage IIIB includes students who, in attempting to think beyond the realm of perception, are limited to analogies borrowed from the familiar and tangible. A selection of answers from the interviews will explain further the characteristics of Stage IIIA and B.

Straight Line:

Interviewer: I see you have chosen e) none of above. What then do you think would be left?

Student: Let's see, (draws it). You'd have a line, and you'd cut it, (he does this to the drawing), and cut it, and go on ... I think you would be left with something but it wouldn't be nothing.

Interviewer: Can you suggest what the something could be?

Student: Something between b) small line and c) point the shape of line.

Interviewer: Why?

Student: I don't know, I don't understand why that would be left, but I feel it would be.

Interviewer: If I joined together a series of points, what would be the result?

Student: A small line.

Interviewer: And how many points would there be in the line in the questionnaire?

Student: Well ... um ... it's 10cm long, that means maybe several hundred. I don't know. Hard to say exactly.

Interviewer: And could you cut up this line until it's nothing but points?

Student: Yes .... no, (hesitates). No because they'd always be something like very small lines.

The above student exhibits Stage IIIA thinking. Another example follows.

Interviewer: If you've put e) ... what do you think would be left?

Student: You wouldn't be left with nothing.

Interviewer: Why?

Student: I don't know ... No idea, but it must be something like both b) and c) - somewhere in between them.

Interviewer: If I joined together a series of points, what would be the result?

Student: A row of points.

Interviewer: And if I put the points close together so they were touching?

Student: A line of points.

Interviewer: Is a line made up of points?

Student: Some can be, if that's the way you make up the line.

Interviewer: Some?

Student: Yes, but most lines are made up of lots of fractions of a line.

Interviewer: And how many would there be in a line?

Student: Depends on how long the line is.

The above responses from Stage IIIA indicate a degree of intuition which Piaget notes as bridging Stage IIB and Stage IIIA. Their intuition prompts the student toward a slightly more advanced answer in terms of knowing that something like a point the shape of a line would be left, something smaller than a line, but the student has no way of being able to understand or explain his answer. In response to the question on points making up a line, the student is capable of reverse operations in reconstructing a line, which he is unable to do in Stage II. In Stage IIIA however, the points possess a shape and exist in finite numbers. Stage IIIB is moving towards the infinite, when the students realise that there could be an extremely large number of points in a line.

Interviewer: You chose c); if I joined up a number of small lines what would that make?

Student: A longer line.

Interviewer: And if I joined up a series of points?

Student: (laughs) I see you are trying to trap me a bit: No, I guess you'd get a line, but if you cut it up, you'd go on cutting up something the shape of a line.

Interviewer: And how long could you go on cutting it up?

Student: Almost forever in theory, but it wouldn't be practically feasible because you couldn't see what you were doing. You'd go on 'til it wouldn't be a line anymore.

Interviewer: What would it be?

Student: I'm not sure, but somehow it would still have to be the shape of a line. It would always keep the shape it was. Maybe, though, you could get lots of squares.

The student quoted above exemplifies Stage IIIB thinking. He is able to reconstruct the line, called reverse operations. He is approaching the infinite in "...almost forever...", and the shape of the point diminishing from that of a line to a square. Finally, he is unable to reconcile a contradiction in his thinking - he realises a series of points can make a line, but cannot imagine reaching the extent of points in subdivision. From the interview it is evident that he was relaxed, and although he felt the interviewer was "...trying to trap..." him he felt strongly enough about his thoughts to keep to them. Close though he is to understanding the concept of infinity, concrete operational thinking does not include hypothetico-deductive abilities. Piaget explains: "...that an attempt is being made to reconcile the operations developed on the material (visible)... which model the invisible on the pattern of the visible and fail to resolve the ensuing contradictions for lack of an operational mechanism (i.e. formal operations)" (Piaget, 1967, p.141). Only formal operations are capable of encompassing the concept of infinity.

The shape of the ultimate element - something between b) and c) or a point the shape of a line, or in the case of the triangle, a point with either a slight peak or the shape of a triangle - is an important aspect. It signifies a difference between Stage II and III. In Stage II, the student is unable to see the part - a point - as making up a whole: the line. Something is either a point or a line, but points cannot make up a line. Whilst in Stage III, the student recognises the whole and its constituent parts, being able to produce either of the two by processes of taking apart, or reversing to put together. The shape of the ultimate element however is seen as isomorphic with the whole. In summary, Stage III is still limited to concrete operations, working with the visible and finite.

Stage IV

Line:	point without the shape of a line
Triangle:	point without the shape of a triangle

Unlike Stage III, Stage IV thinking performs formal operations of thought enabling the student to subdivide a whole indefinitely. Similarly for the reverse operations, the student can conceive of joining the parts of the whole together - recognising that an unlimited number of elements can form the whole. One example of Stage IV thinking follows.

Interviewer: When you subdivide the line I see you chose d), that one would eventually be left with a point without the shape of a line. If I joined together a series of points, what would that make?

Student: A line.

Interviewer: How many points would be needed to make a line 10cm in length?

Student: You couldn't count them. An infinite number.

Interviewer: What shape would the points have?

Student: They wouldn't be bound by shape.

Interviewer: And for how long could you carry on cutting up a line?

Student: Indefinitely.

The interview above also brings out that the student is not limited to the material or visible. No student in this category needed to draw diagrams for himself whilst thinking through the questions. The students have moved away from the limitations of visible subdivisions and perceptible points. One student stated that a point was "... beyond shape", exemplifying the fact that formal operations extend beyond any physical limits. Below is an example of a student who, during the interview came to reconsidering his original response, changing from Stage IIIB to Stage IV. The student had chosen c), that on subdivision one was left with a point the shape of a line. The interview continues.

Interviewer: If I joined together a number of small lines, what would that make?

Student: A line.

Interviewer: And if I joined together a series of points, what would be the result?

Student: Also a line I suppose ... but I'm thinking ... so if you cut it up you'd be left with a small line ... but that would also be made up of points ... Or, so I see! You'd be left with a point.

Interviewer: And for how long could you carry on cutting it up?

Student: Oh, forever; you'd go on ad infinitum.

In the interview situation it becomes evident how committed a student is to the answer he selects (Osborne and Gilbert, 1979). The student quoted above may have been in a transitional stage between IIIB and IV, and the interview provided stimulus and an opportunity to reconsider his answer. The student was classified as Stage IV on this task.

When the responses are analysed in detail, the tasks involving infinity clearly indicate students' levels of conceptual understanding of the concept. The importance of these tasks lies in three areas. Firstly, it indicates the level of thinking students are capable of regarding the concept of infinity, and therefore what selection of abilities a class contains. Secondly, infinity is an aspect of the concept of space. Those students who are not capable of formal thinking regarding infinity may be limiting their understanding of the concept of space to the finite and visible. Concepts such as geographic, economic and social space, and diffusion, all require a concept of space not limited to the visible, but employing thinking which is hypothetico-deductive and transcends the material. Thirdly and finally, students' performances on these tasks are recorded and used in the analysis of the postulated hierarchy.

b) Q3. The above shows a piece of cardboard ...
What would be the shape of the perimeter described by the cardboard?

Response types	No. of students	Piagetian level	Mark allocation
Did not know at all	2	-	0
a) cube 	-	pre-stage II	1
b) cube tilted 45^{o} 	5	stage II	2
c) 3-sided pyramid 	1	stage II	2
d) 	7	stage II	2
e) 	23	stage III	3

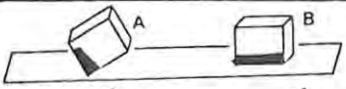
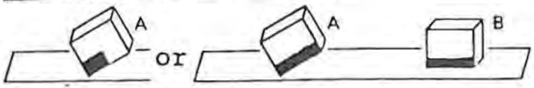
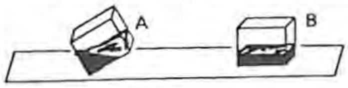
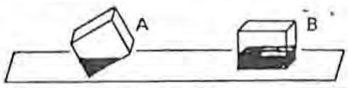
The task required the student to mentally relate the two-dimensional figure, the square, to the rotation of its three-dimensional solid. The interviews established that the two students who did not answer the question, did not do so because they neither knew the answer nor wanted to guess. The results indicate that approximately forty percent of the students did not have the ability to imagine the rotation of a surface. Such a high percentage is not surprising in view of Good's (1977) fifty-five percent of college students who indicated on the same task a lack in their concept of projective space.

The alternative shapes given as possible answers in the multiple choice question were taken from Good's (1977) study. However the pilot study showed that Good's (1977) fourth alternative was not viable for the students tested. After interviews with the pilot study students, a substitute fourth alternative was formed which then proved to be the second most popular alternative. In both the study by Good (1977) and the present study, the second alternative, the cube tilted forty-five degrees was also popular. The choice of the fourth alternative shows the student realised curved lines will be produced on rotation but could not select which lines were involved. The cube tilted forty-five degrees indicates the student was able to construct mentally the six sides of a cube, but could not rotate the cube correctly. The popularity of these two alternatives suggests that they are common mistakes. The correct answer requires the student to be able to co-ordinate viewpoints: the cardboard hanging and then rotating.

If an understanding of projective space is necessary for understanding Euclidean and abstract space as Piaget indicates; and if Stage III thinking is necessary to master projective space, only those capable of Stage III and IV thinking abilities in the concepts of space are likely to comprehend Euclidean and abstract space. In other words, approximately fifty percent of students could be expected not to master Euclidean and abstract space concepts. However, student's thinking abilities seem to be inconsistent, since, in the water level task, sixty-six percent demonstrate an understanding of Euclidean space. The implication here is that although the tasks have been tested and validated, a single task does not sufficiently reflect a student's overall operational abilities - only his capability on the specific task set.

c)

> Q4. The diagram below shows a water tank ...
> Complete the diagrams below ...

Response types	No. of students	Piagetian levels	Mark allocation
	9	III	3
	4	III	3
	7	IV	5
	18	IV	5

The water level task tests the student's use of systems of reference. For example, if the student uses the tank as a system of reference, when the tank is tipped, the water line will tip with the tank. The water line is then drawn with reference to the tank only, resulting in the diagram below, which would be classified as a pre-operational (Stage II) response.

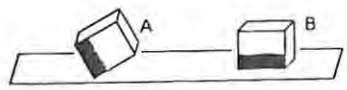


Figure 11: Pre-operational response to the water level task.

In testing the use of systems of reference, the task is testing the student's understanding of a concept of space which is transitional between projective and Euclidean. Below is an explanation of the responses. No student demonstrated Stage II characteristics.

Stage III

During Stage III there is conflict between taking reference cues from the tank, or taking cues from the horizontal and verical contours of the surroundings which remain constant. The conflict results in the two types of Stage III responses above. Some students drew the water level very slightly tilted. In the interview it was clarified as to whether the student meant the water to be horizontal or drew carelessly, or whether the drawing was an actual representation of the students' thinking. In all cases the student meant the water to be at a slight angle off the horizontal. This response is typical of Stage III.

Stage IV

The distinctive ability of the final stage is the co-ordination of all angles and parallels, horizontal and vertical in the surroundings - the tank, the water, as well as all objects external to the tank. The student is able to consider systems of reference apart from the tank, just as in the landscape sketch. The stage IV student is able to consider the whole landscape model when focussing on a part such as the location of a town.

Approximately sixty-six percent or twenty-five students exhibited formal thinking on the task. The relevance of the task is that it demonstrates the important role of systems of reference. A system of reference outside the tank is necessary to indicate whether the water level has or has not altered through the movement of the container. One vital application of such a concept, is that in the same way with the water level, a relative movement or a relative position cannot be understood without a system of reference. The landscape sketch utilises this concept as will be seen in the discussion of the sketches. Once the students utilise a reference system external to the tank, the task becomes one of comparing angles, parallelism, and distances and in doing so, form the basis for a system of co-ordinate axes. Co-ordinate systems also arise in the landscape task and will be discussed in some detail.

d) Q5. Sketch of the model landscape as viewed from the north.

Response types	No. of students	Piagetian stage	Mark allocation
Could not do it; could not begin	3	IIA	1
Linear diagram; objects incorrectly ordered Left-right relationships reversed	8	IIB	2
Left-right relationships incorrect Before-behind relationships reversed Incorrect ordering of objects distances and scale inaccurate	3	IIIA	3
Left-right relationships correct Before-behind relationships incorrect Improved distances and scale Three-dimensional diagram	18	IIIB	4
Left-right relationships correct Before-behind relationships correct Accurate distances and scale Three-dimensional diagram Use of an abstract co-ordinate system	6	IV	5

The layout diagram embodies the need to master distance which is a synthesis of the concepts: surrounding, enclosure, order, separation and connectivity; proportion and ratio; projective and Euclidean co-ordinate systems. The students who could not begin a drawing on the questionnaire were found to have a vague idea of how to proceed when it was discussed in the interview. Hence the students were classified as Stage IIA, rather than a lower stage. One student had not seen the question and so completed the task during the interview and was subsequently allocated to a stage. The characteristics of each stage are detailed, and the students' diagrams illustrate the growth of concepts.

Stage IIB

When asked to view the model landscape from the north, five students, (approximately fourteen percent of the total) of the eight in Stage IIB drew what Piaget termed a bird's eye view, rather than an oblique view, this aspect was interpreted not as a projective problem but as a problem of confusion between north and vertical. The remaining three students drew a linear diagram, with all the objects in the model landscape strung out in a line. The linear sketches suggest a difficulty with projective space, as well as in two cases a problem of drawing three-dimensions. The other of the three drew the buildings in three dimensions, but not the whole landscape.

The objects - towns and mountain ranges - were placed in the reverse order. Distances were incorrect, and the objects which were to be located in the background of the sketch (the 'behind'), were in two of the linear sketches placed in the sky area. These errors are identical to those found by Piaget for Stage IIB and the following explanation is based on Piaget's conclusions (Piaget, and Inhelder, 1967).

Order is a pre-requisite concept for distance and since order was incorrect, both the left-right order and before-behind order, it would be expected that distance estimates would also be incorrect. The left-right order error indicates that the student is not capable of projective thinking. Before-behind are a dimensional problem, and is generally corrected only by stage IV and after the left-right correction which is generally made by Stage IIIB. Distance requires an understanding of proportion and ratio for estimates of correct size and relative distance. Both proportion and ratio require Stage IV operational thinking.

Stage IIIA

Left-right relationships are no longer systematically in the reverse order, but there is still confusion with some of the objects. Before-behind relationships are still reversed, implying that use of projective co-ordinates is still not possible. Distances and scale are still inaccurate.

Stage IIIB

By this stage perspective has been mastered, and left-right relationships have been corrected, indicating an improvement in projective operational thinking and enabling three dimensional diagrams. Before-behind relationships are no longer systematically in the reverse order from the correct, but the student is confused as to their relative positioning. Distances are improved. The latter two points - relative positioning and distance, are linked to the responses in Section I where students were asked to explain distance and location. Not until Stage IV can a student refer to an object in terms of its distance or positioning relative to another object or objects. By Stage IIIB however, students are beginning to use a projective co-ordinate system using natural co-ordinates. In other words, projective abilities are used to approximate the location of objects, and the natural co-ordinates are objects - mountains, towns - used to guide the student to locating an object in the diagram. By Stage IV natural co-ordinates are substituted by abstract co-ordinates such as a map, with co-ordinates of, for example numbers and distances, which are not part of the diagram itself. The use of a projective co-ordinate system demonstrates the ability to co-ordinate the diagram as a whole from a projective stand point.

Stage IV

By Stage IV the student is able to co-ordinate the diagram as a whole from both a projective and Euclidean standpoint. This is demonstrated in the former case by the ability to see the objects in relation to the surroundings, and in the latter case, by the mastery of distance, ratio, scale and proportion. The mastery of distance and proportion is begun in Stage IIIB, but is completed along with accurate measurements and an abstract co-ordinate system. The use of an abstract co-ordinate system used by the students of the present study, were discussed in the interviews. Examples of systems used included a strip of paper marked in sections, a ruler, and a grid system. Some of the poor diagrams may have been a result of the task being the last on the questionnaire and students were wanting to finish. Discussion in the interviews did little to establish whether this was the case or not.

The results suggest that eighty-eight percent of the students were unable to complete a diagrammatic layout correctly. The remaining twelve percent or six students, in their ability to perform the task correctly demonstrated formal thinking abilities. Besides the task being useful for displaying an array of abilities, the reasoning abilities required for the task are commonly demanded as skills in geography. The skills range from a student being able to use maps, and to design his own map and hence abstract co-ordinate system and scale, (requiring mastery of ratio, proportion, distance, Euclidean space), to perception of distance for different members of a community (requiring projective abilities as well as Euclidean). From the experience at Rhodes University, scale has been taught during the first half of first year geography to enable other skills to be developed, for which scale is a prerequisite concept. Scale is however a deceptively complex concept and has been extremely difficult for students to grasp, with some students still finding difficulty in third year. The reason for the difficulty may be due in part to the fact that it requires formal thinking ability. The analysis of the scale and ratio task below will add to this discussion.

e) (Section I) Q2C (iii). Scale is the ratio between map distance and the actual ground distance that the map represents ... What would be the scale if ...?

Response types	No. of students	Piagetian level	Mark allocation
Did not know	1	-	0
1:150 000	1	-	0
1:100 000[2]	2	-	0
2:50 000	1	-	0
0,5:50 000	2	-	0
1:50 000	6	-	0
1:200 000	25	IV	5

The understanding of ratio is not fully developed until formal operational thinking is reached at Stage IV (Piaget and Inhelder, 1967). There is no generally accepted method of classifying the different responses to ratio problems such as listed in the response types. Classification and mark allocation was only made in respect of the correct answer which requires Stage IV abilities. The allocation of five marks to Stage IV, and no marks for the other responses, will heavily weight the formal thinkers on this task. However it is not an obscure concept, but rather one with which every student is very familiar.

The large number - twenty five or approximately sixty six percent - who gave a correct answer could be due to a number of reasons. Students may have been able to apply a formula learnt by rote, whilst not understanding the process. The unfamiliar construction of the question was an attempt to reduce the successfulness of applying a rote formula. Another reason could be that the model landscape was given to them in a visible or concrete form, and the student was not required to imagine the landscape a different size. The student may then have used the visible to operate as much as possible in concrete terms.

The scale and ratio task cannot be considered separately from the sketch of the model landscape where scale and ratio were important. It is relevant to point out that the Stage IIIB and IV sketches, where scale was 'improved' and 'accurate' respectively, numbered twenty four. Those capable of the ratio task above numbered twenty five. All but three of the twenty five were included in the twenty four; and the six 'accurate' scale sketches belonged to students all of whom performed Stage IV thinking on the ratio task.

f) (Section I) Q2B (i), (ii), and (iii). Adaptation of the Islands Puzzle. This question concerns the four towns A, B, C and D...

First clue: People can go by bus between towns C and D.
Second clue: People cannot go by bus between towns A and B.
Use these clues to answer Question (i). Do not read the next clue yet.

i) Can people go by bus between towns B and D? ...
Third clue: ...People can go by bus between towns B and D.
Use all three clues to answer Questions (ii) and (iii).
ii) Can people go by bus between towns B and C? ...
iii) Can people go by bus between towns A and C? ...

The method of analysis of the puzzle was similar to that used by Karplus and Karplus (1970), and Blake, Lawson and Nordland (1976) which was found to be acceptable. The only modifications made for the present study were the scoring and the titles of categories in order to maintain a consistent pattern throughout the whole of this study.

The categorisation of a student's responses entails a subjective element. Tentative categories designed by Karplus and Karplus (1970) were ratified by Blake et al (1976) and so were adopted for the present study. A major difference exists however, in that Karplus and Karplus (1970) were unable to check the reasoning of students in an interview situation owing to large numbers. The responses, if brief or ambiguous, were left to the interpretation of Karplus and Karplus (1970); or if students did not explain their first answer, Karplus and Karplus (1970) stated they used the student's answers to Questions (ii) and (iii) to interpret the Question (i) answer. The interview in this study served to overcome the further subjective element of interpreting responses by asking the student to elaborate on his reasoning. A description of the categories of explanations follows (Karplus and Karplus, 1970, p.400).

Response type	No. of students	Piagetian Stage	Mark allocation
Explanation with no reference to the clues and/or introduces new information.	6	IIA	1
Direct appeal to, or repetition of clues. Since all questions require inferences, a direct appeal to the clues does not provide a logical justification.	12	IIB	1
The clues are used to form concrete models which are then used to make predictions.	7	IIIA	2
The logical inference from the two positive statements, first and third clues, to answer Question (ii).	7	IIIB	2
Logical explanations to: question (i)	3	IV	2
question (ii)	2		3

Excerpts of interviews or from questionnaires will further clarify the differences between categories.

Stage IIA

Reasoning is pre-logical which is illustrated by explanations which only repeat the answer to be explained, appeal to the diagram itself or what Karplus and Karplus (1970) term fanciful stories. Some examples are given in respective order:

Student: (from questionnaire, for Q(i)). No, because they can't get there.

Interviewer: Why can't they get there?

Student: Because they aren't able to.

Student: (from questionnaire, for Q(ii)). Yes, because the physical features aren't so difficult to overcome.

Another Student: (did not answer in questionnaire, for Q(ii)). I didn't know how to write it, but I'd say no, because the bus wouldn't be able to make it over the mountain most probably.

Stage IIB

Students in this stage should be thinking transitionally towards using concrete models. A typical answer for this category is:

Student: (for Q(i)). Can't tell because you're not told from the clues.

Stage IIIA

The most common model provided for the possibility of the bus service being uneconomical resulting in the service being withdrawn.

Student: (from interview on Q(i)). Can't tell, because the towns are isolated and the bus service would be non-productive and probably stop running.

The reasoning is clearly advanced compared to Stage II, in the model-based approach. However, the students are assuming information which is not given; and the models are concrete, and hence not transferable to a new situation.

Stage IIIB

Karplus and Karplus (1970) state that the logical inference required from the two positive clue statements needed to answer Q (ii) demands reasoning which is transitional between concrete models and abstract logic. Hence only the explanation for Q (ii) is relevant to this stage. A logical explanation to Q (ii) is:

Student: (from questionnaire). Yes, from B to C via D.

Stage IV

Questions (i) and (ii) require abstract logic. Examples of correct answers are:

Student: (for Q(i) from questionnaire). Cannot tell because we are not told of any bus connections between A and C or with B.

Another
Student: (for Q(iii) from interview). No, because if they could, it would mean people could go between A and B by going via C and D, and that would contradict the second clue.

The answer to Q(iii) is difficult, as exemplified by Karplus and Karplus' (1970) study where only thirteen (eighteen percent) of the sixty nine members of the American Association for Physics Teachers tested, gave the correct answer. In the present study only two (five percent) of the thirty eight students were correct.

The correct answer pattern is (i) Cannot tell; (ii) Yes; (iii) No. Karplus and Karplus (1970) found that twenty five percent of the sixty nine physics teachers had the total number of correct answers. Of the Rhodes geography students tested, six (15,5 percent) achieved the correct answer pattern, with two of these giving the wrong reasons.

It is difficult to suggest reasons for the low performance level. On the one hand, Karplus and Karplus (1970) suggest that the style of a task rather than the intellect level of a subject influences the level of abstract thinking employed. In an attempt to overcome this possibility, what was originally the Islands Puzzle was changed to a familiar geographical context, and was placed in Section I of the Questionnaire amonst the specifically geography-type tasks rather than with the more abstract tasks of Section II. On the other hand, studies by Karplus and Karplus (1970) and Fuller, Karplus and Lawson (1977) indicate that such a low percentage is not surprising. It rather emphasises that abstract logic or formal operational thinking is not commonly displayed. As a reasoning task, the puzzle displays the varied reasoning patterns adopted by students, and demonstrates clearly the differences between Piaget's levels of concrete and formal thinking. Debate has begun as to whether the puzzle does test Piagetian operations; no conclusions have been drawn as yet. Indeed, those investigating the debate ask that if the puzzle does not measure abstract reasoning ability, then what is being measured by the task remains to be ascertained (Blake, Lawson and Nordland, 1976).

Although such uncertainty typifies the problems encountered in cognitive research, the puzzle has been administered with apparent success since the debate began (Fuller, Karplus and Lawson, 1977) and uncertainty is no reason to terminate the use of research tools under question. Indeed, uncertainty challenges research in the very area being questioned. In the light of the results of the puzzle in the present study, further research on geography students would appear valuable. If the majority of geography students do not use formal reasoning, such a fact firstly needs to be recognised, and secondly requires a response from the teachers. The puzzle, as mentioned above, can be a heuristic device in stimulating students towards developing formal reasoning abilities. Fuller, Karplus and Lawson (1977) emphasise that if teachers are aware of what is involved in reasoning abilities, available tools and methods may be administered to help extend the students toward their potential reasoning capabilities. Such a challenge is one of the implications of Piagetian research. Further implications will be discussed in the overview.

2. Overview of all responses to the Piagetian-type tasks.

The overview will briefly deal with all results as a whole before dealing with each of the hypotheses. The implications of the results will then be discussed in terms of the present study as a whole, and with regard to Piagetian research in geography.

Piaget's original notion was that all people would use formal operational thinking consistently by the age of approximately seventeen years. The present study has revealed results similar to many recent studies in that on a range of tasks university students either do not display characteristics of formal thinking at all, or the majority of students are not able to use formal reasoning consistently on all tasks. Only one student in the study exhibited formal reasoning on all five tasks, and three students did not demonstrate features of formal reasoning on any task (Fig. 8). The majority of students - thirty four - were inconsistent in their ability to use formal reasoning. It is for these students that teachers need to be alert to their understanding of concepts. Fuller, Karplus and Lawson (1977) suggest that such a group of students can often appear to be reasoning at the formal level or understanding formal concepts in subject matter, when in fact they are using memorised phrases or patterns of thinking which they do not fully understand.

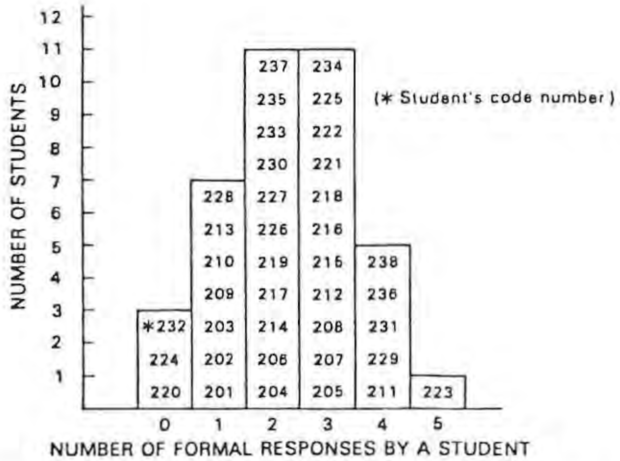


Figure 8: Frequency with which students demonstrate formal thinking on the Piagetian tasks: possible maximum = 5 (N=38).

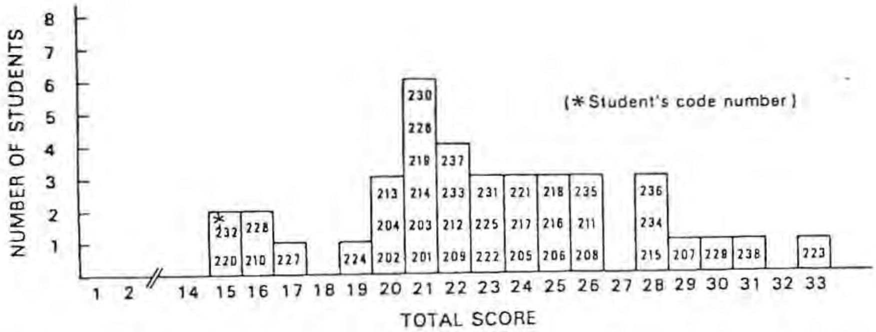


Figure 9: Distribution of total scores for each individual on the Piagetian tasks: possible maximum = 34 (N=38). (* student's code number)

Keeping the student's tendency to exhibit different abilities in mind, students' total scores were plotted on a histogram (Fig. 9). The total scores do not indicate the student's formal reasoning ability, since it offers no information as to whether the score was gained from formal and concrete responses, or only concrete for example. The code numbers however, show that with reference to Fig. 8 the three students who did not exhibit formal thinking on any task, are amongst the six lowest total scores (students 220, 224 and 232). Similarly, the student who demonstrated formal thinking on all tasks obtained the highest total score (student 223). Of the nineteen students (fifty percent of the sample) whose total score was twenty two or less, eighteen of these demonstrated formal thinking on two or less tasks, thus indicating the approximate relationship between the two figures. It remains to consider each of the hypotheses posed for the tasks. Each hypothesis will be given, followed by a brief discussion in view of the previous analysis of the relevant responses. A statement is then made as to the acceptance or rejection of the hypothesis. A discussion of the implications of the resultant statements will follow.

Hypothesis I : There will be students in the sample unable to exhibit formal operational thinking in the tasks on an aspect of topological space.

The aspect tested was infinity, where fifteen (approximately forty percent) students performed consistently with formal thinking on both tasks. The remaining twenty three (sixty one percent) were not able to exhibit formal thinking. Concrete thinking was demonstrated by thirteen of the twenty three students on one task, whilst displaying formal thinking on the other task. Consistent responses of concrete reasoning for both tasks was given by five of the twenty three, and two students displayed pre-operational thinking in at least one task. The null hypothesis that there will not be students unable to exhibit formal operational thinking on the tasks on an aspect of topological space can be rejected for the sample of students tested.

Hypothesis II : There will be students in the sample unable to exhibit concrete operational thinking in the task on aspects of projective space.

The piece of cardboard task was used to test the aspect of rotation and development of surfaces. The correct answer requires Stage III abilities (Table 1). Projective space does not require Stage IV thinking. However, the inclusion of a task on projective space is essential for an understanding of Euclidean space since they are mutually interdependent (Piaget and Inhelder, 1967). If students are unable to understand Euclidean space, their inability may be traced to a student's problem in projective space. Of the sample of students, fifteen (forty percent) students could not use Stage III thinking to perform the task correctly. The null hypothesis that there will not be students unable to exhibit concrete operational thinking in the task on an aspect of projective space can be rejected for the sample of students.

Hypothesis III: There will be students unable to exhibit formal operational thinking in the tasks on aspects transitional between projective and Euclidean space.

The transition is a complex stage and warrants three tasks, bearing relevance on each other. The water level task examined the aspect of systems of reference which is prerequisite for the ability to use a co-ordinate system as in the landscape task. The landscape task explores students' understanding of projective and Euclidean concepts of space - co-ordination of viewpoints; co-ordinate systems; and proportion, ratio and scale. The scale task is used to test explicitly students' ability to use the concept of ratio. On the three tasks, thirteen, thirty two and thirteen students respectively could not exhibit formal thinking on the tasks. The null hypothesis that there will not be students unable to exhibit formal operational thinking in the tasks on aspects of the transition from projective to Euclidean space is rejected for the sample of students examined.

Hypothesis IV : There will be students in the sample unable to exhibit formal operational thinking on the puzzle testing abstract reasoning ability.

The bus service puzzle was used to assess students' intellectual development in abstract reasoning. The puzzle demands a high level of formal thinking. Only two students consistently displayed formal thinking, thirty six (ninety five percent) students did not. The null hypothesis is that there will not be students unable to exhibit formal thinking on the puzzle testing abstract reasoning ability.

The implications of the statements regarding the hypotheses need to be discussed. Contrary to the assumptions of most developmental psychologists' and educationists' results of recent studies, suggest that over a third of American University students and adults do not use formal operational thinking (McKinnon and Renner, 1971; Schwebel, 1972; Fuller, Karplus and Lawson, 1977; Kolodiy, 1977). The results of the present study indicate that Rhodes University students are no different. Students not exhibiting formal thinking on the tasks ranged from thirty four percent on the ratio and water level tasks, to ninety five percent on the abstract reasoning puzzle. If the results and analyses bear witness to the students' capabilities, what does the prevalence of a lack of formal thinking ability mean?

C. ANALYSIS OF PERFORMANCE ON TASKS CONCERNING THE SELECTED CONCEPTS OF SPACE IN GEOGRAPHY

In both literature and teaching, geographers have a tendency to introduce concepts implicitly, leaving the student to structure the concepts himself (Hudman, 1972). A large number of the concepts concerned must necessarily be concepts of space, since the geographic point of view is spatial (Gregory, 1978). The spatial viewpoint encompasses concepts and processes relating to spatial integration, spatial interactions, spatial organisation and spatial processes (Berry, 1968; Sack, 1972). Despite the centrality of spatial terms in geography, geographers use the concepts even though the meanings remain imprecise (Sack, 1973). If geographers experience difficulty in defining the concepts, how do students manage? The tasks on concepts of space analysed in this section seek to answer the question by aiming to establish some of the difficulties experienced by students and to discover the main misunderstandings. In order to do this, the application of concept analysis in geography and the use of Piagetian theory is explored, since such analysis in geography has not been previously employed.

Analysis of students' responses is made for each task, with the tasks being dealt with in an order slightly different from that of the questionnaire, to facilitate reference to the relationships between tasks. Unlike with the Piagetian-type tasks, students' responses are not given mark allocation in the tasks on spatial concepts for two reasons. The first is that the present study is exploratory, and there have been no previously tried scoring methods due to there being no similar analyses in geography. Secondly, total scores yield little information about an individual student's reasoning ability, and testing the hypothesis for this section does not demand total scores. Responses to each task are, however, discussed in detail. The detail is necessary to make explicit the students' patterns of reasoning, and to clarify the basis on which conclusions are drawn. The analysis aims to highlight the most important aspects, and hence the majority of responses are dealt with in depth, whilst a few are mentioned only in passing. It is realised that in some cases, the detail does not fully exploit all the information embedded in the students' responses. The study is limited in space, but further analysis would be valuable for teachers involved with the students.

Two points about the method of analysis need to be made: the true/false responses required in assessing given statements are not seen as important as the explanation for their response which is analysed instead. The explanations were very revealing, embodying the students' assessment of true or false within their explanations. The second point is that students' responses categorised as "did not know" were not allocated a Piagetian stage referred to by 'response type'. Unless it could be clearly established why the student did not know, there was no basis on which to classify the student for example as concrete or pre-operational on that particular task.

What follows is a question by question description of the results to the questionnaire and interviews. Examples are cited of typical or particularly interesting responses to both the questionnaire and interview questions. For convenience, abbreviations of the questions are given, but reference can be made to the questionnaire in the appendix for the full wording. The results will be discussed after each question has been dealt with individually.

1. Question by question analysis

Students' responses to Q1 only will be described initially. During the analysis of the questions following, relationships between Q1 responses and later responses will be referred to and analysed in the context of other responses.

SECTION I of the questionnaire

Q1 Briefly explain what you understand by ....

Q1 (i) Location

Response types	Response examples	No. of students
Indication of physical/ concrete understanding	"The positioning of an object; "where"; "the siting"	26
Indications of abstract/ formal understanding	"area occupied by... relative to ...." "position in relation to..."	12

Three students used the terms 'space' (e.g. "position in space"). Four students used the term 'geographically' (e.g. "the situation .... geographically"). What the students mean by 'space' will be revealed in their answers to Q3 on the concept of 'space'. If the student understands location in terms of its relationship to other objects, his concept has developed beyond the topological type of space to that of either projective or

Euclidean as outlined in the analysis of the Piagetian-type tasks. The student no longer limits his understanding of location to the object (e.g. town) itself, but sees it as part of a whole system. His understanding of 'space' will influence how he uses the term 'location'.

Q1 (ii) Distance		
Response types	Response examples	No. of students
Exhibiting concrete understanding	"Amount of space between two points ... measured in kms" "Physical distance ... measured in kms" "Length/area between two points ... measured in m, kms"	23
Exhibiting formal understanding	"Space or area between ... measured in kms, time, cost" "The separation of X from Y... measured in kms, behaviour patterns." "Stretch of earth's surface which can be physical, social etc ... measured in infinite ways - physical units, social units/ interaction etc.".	15

Twelve students used the term 'space' explicitly. Responses by students in the category of concrete understanding of distance represented concepts of space which were limited to absolute space, and can understand distance as being measurable only in units of physical distance. The concept is hence limited to distance being a stretch of land, which is visible and hence is seen in concrete terms.

Relative distance requires formal understanding, and is a concept high in the hierarchy. Students' ability to understand distance in relative terms can be traced to their ability to demonstrate formal thinking on the Piagetian-type tasks and their understanding of space in relative terms.

Q1 (iii) Interaction		
Response type	Response examples	No. of students
Concrete (three categories)	a) contact/activity between two places cannot be measured.	a) 7
	b) communication/activities ... measured by "effects"; "net results"; "what it depends on".	b) 8
	c) exchange/activities between two places measured in "percent" "age"; "population" "density" "profit"	c) 13
Formal	"Communications and/or involvement between places ... measured in number of transactions"; "... frequency of visits, contacts".	10

The thirteen students in category c), confirmed in the interview that they could name some of the measures of interaction but had no idea how to use them as measures. From the questionnaire these students had been listed as capable of formal thinking on this task, but as a result of the interviews, were placed in their own category under concrete response types.

Once again, students who respond indicating formal understanding can be traced through the questionnaire to establish tentatively how their responses are related and why some students are able to understand the concept on the abstract and formal level, and others only on the concrete. This could indicate a misconception.

Q1 (iv) Proximity		
Response types	Response examples	No. of students
Concrete (three categories)	a) did not know	a) 7
	b) "In the area"; "area surrounding"	b) 8
	c) "nearness"; "closeness"; "influenced by relief; physical barriers".	c) 8
Formal	Distance from...nearness...can be influenced by "perception", "technology" "legislation or law."	15

No student who demonstrated an understanding of proximity as "a given area around a point" saw the only influence as physical, e.g. mountains. A phrase used by over fifty percent of students was "proximity is the surrounding". A possible confusion which was revealed in interviews was the common use of the phrase "in the proximity of...". Students interpreted the latter phrase as meaning "within close physical distance". Those responses in the formal category indicate proximity as being influenced by factors other than physical distance. The other factors mentioned are abstract concepts. Students' performance on this question should be related to their concept of distance. Fourteen of the fifteen responses categorised as formal were by students who had responses to distance also categorised as formal. There would appear to be a relationship between the concepts, such that unless distance is able to be understood in terms other than physical, the concept of proximity is limited to physical terms.

Q1 (v) Accessibility		
Response types	Response examples	No. of students
Concrete (two categories)	a) did not know	a) 5
	b) "reachability"; "determined by physical landscape"	b) 10
Formal	"The ease with which something is contacted or reached"; determined by "time and cost"; "technology and transport".	23

A formal understanding of accessibility requires that a relationship or interaction between places or people be seen as influenced by factors other than physical distance. Accessibility is an important prerequisite concept for commonly used concepts such as economic space and social space; and is essential for the understanding of principles of location theory. There is a need to establish whether students whose responses were categorised as concrete, generally perform only on the concrete level. In which case, the student first needs to reach formal operational thinking before being able to understand accessibility on the formal level (see Fig. 5).

Q1 (vi) Distance Decay		
Response type	Response examples	No. of students
Concrete (three categories)	a) did not know	a) 13
	b) "Distance reduced by improved communication"; "shortening of distance".	b) 6
	c) "Shopping activity breakdown with distance."	c) 10
Formal	"With an increase in distance (from a centre) there is a reduction of activity or services."	9

Category b) would appear to require formal thinking in terms of an implication of a space other than simply physical space, but on interview were revealed to be rote-learned definitions for space - time convergence. Category c) has been included in concrete, since distance decay was seen as the reduction of one particular type of activity. Students could not understand the concept apart from the familiar concrete examples they had been exposed to, and could not apply distance decay to a new or unfamiliar situation presented to them. This was confirmed in the interviews.

Seven of the nine students who responded on a formal level, gave responses which were categorised as formal on the concepts of location, distance, interaction, proximity and accessibility. There appears to be a relationship between the concepts, requiring understanding of the abstract nature of the lower concepts. However the remaining two students were categorised as concrete on the concepts of proximity and accessibility. Reasons for this could be that formal understanding of proximity and accessibility are not prerequisite for formal understanding of distance decay. Another reason could be a failure in the questionnaire and interview to distinguish between responses which indicated formal and concrete thinking. Finally, the students may have been able to repeat for distance decay that which had been memorised but not understood.

Economic Space - Questions 2A(i), (ii); 4(i), (ii), (iii), (iv).		
Q2A The baker's travel pattern:- (i) the most important consideration he should make; (ii) units of measure.		
Categories of Responses		No. of students
2A(i)	2A(ii)	
d) cost and time	d) km, cost and time of travel	10
d) cost and time	c) cost and time	16
other		12

The second most common category selected - viz. 2A(i)d and 2A(ii)d - indicates that although the student sees cost and time as important considerations, he does not see distance in kilometres as being part of cost and time. The category 'other' encompasses a number of different combinations selected by students. Where a student's particular combination in this category bears implications or relevance to his responses to other questions, these will be brought out in the discussion following the description of all results. However, the interview responses are interesting, and because they shed light on the way the students were thinking, some of the interactions are recorded below transcribed from tape.

An example of concrete reasoning from category 2A(i) :

Interviewer: I see you selected b), meaning that the most important consideration for the baker should be the friction of distance. Could you tell me more of your ideas here?

Student: It's how difficult it is to travel that's the most important thing.

Interviewer: Difficult?

Student: Yes: whether the baker thinks it's alright or not.

Interviewer: And how would he assess whether it was alright or not?

Student: Well...(pause) by whether he thinks it's difficult or not.

An example of concrete thinking, able to refer to concrete situations and not draw on principles:

Interviewer: I see you selected a), meaning that ... Could you tell me more of your ideas here?

Student: Well, it's the baker, some other baker might be selling bread here (points to the town in the diagram). So it's all to do with his threshold ... I can't say anything else because we aren't given any more information.

An example of formal thinking, referring to principles and abstract concepts:

Interviewer: I see you selected d). Could you tell me more of your ideas on this?

Student: Cost and time means in terms of time and travel, and costs, cost-benefit and profit; possible social cost if he supplies a group of people not accepted by the majority; perception comes into it too.

Examples of kilometres not being seen as part of cost and time, from 2A(ii) :

Interviewer: You selected d) km, cost and time of travel. What do each of these units measure?

Student: Km measure how far it is; cost measure how much money he has to spend; time is time to drive there and back.

Another Student: Km is the distance; cost is the price of petrol; time is travel time.

Another Student: Km...I don't know... distance I suppose but now I'm not sure. It must, but I don't see why it's important. But cost and time can't cover <u>everything</u>.

Examples of inconsistent responses:

Interviewer: You have selected 2A(i) and 2A(ii) d). That's interesting. Can you explain your thinking, and say why you didn't select, for example, 2A(ii) c)?

Student's responses included:-

: I don't know...I guess I knew kms had to be in it somewhere.

: I don't know, except that I think 2A(ii) d) stood out a lot for some reason.

: Well, I think kms are important. There might be the problem of hills where it's not flat, so of course that would be important.

Q4 For the concept of economic space ...

i) Briefly explain the concept ...

ii) Choose two situations most representative, and two least representative

iii) Assess the statement ...

iv) Briefly explain ...

Q4 (i)

Response types	Response examples	No. of students
-	a) Did not know	a) 6
Concrete	b) "An amount of space to make money"; "used space"; "efficient use of space".	b) 18
	c) "space in which economics happens".	c) 10
Formal	d) "space comprised of economic activity".	d) 4

Economic space is defined by Hurst (1972) as the spatial organisation of an economy, and can be symbolised by such characteristics as "...time-cost dimension and ... the numerous measures of economic interaction between groups" (Hurst, 1972, p.48). Understanding of the concept requires formal thinking, since, as with social and geographic space, it is comprised of intangible and changeable features.

The students of category a) of Q4(i) displayed no consistency in selecting most and least representative. For example, four of the six students selected industrial site as most representative, yet none of these selected banking site as the other most representative. Only one of the six attempted to explain his answer to (iii), stating that economic space was the same as physical space. The examples of responses are tabled below. The two tables will be discussed together.

Q4 (iv)

Response types	Response examples	No. of students
-	a) Could not explain/did not know.	15
	b) Explain by repeating answer to i).	6
Concrete	c) Economic 'space' is the same as physical space.	5

(cont.)

Response types	Response examples	No. of students
	d) Economic space is the surface of buildings, roads etc.	2
	e) Where economic space becomes uneconomic, it no longer exists.	6
	f) Economic activity needs physical space but has no boundaries and/or can be invisible.	2
Formal	g) Economic aspects such as politics, resources and exchange can be quantified for areas of physical space, and drawn as a surface.	2

The categorisation of responses was not easy owing to the large numbers of different responses. However, key terms and phrases used by the students served to indicate to which category the student belonged. The interviews were used to ask the student to clarify or elaborate on the written responses, and new categories were formed where necessary so as not to force a student's response into a related but different category.

Referring to the tables, four of the ten students in the first table who explained economic space as "...space in which economics happens" were amongst the six students in the second table who for Q4 (iv) responded by repeating their answer to (i) - category b). Further, the same four students were amongst the five in the social space question who used a degree of tautology in category c) to explain their answer; the four also included the two students who in the Piagetian-type puzzle responded by repeating the answer which was to be explained. By tracing individual students' performance thus, patterns of thinking such as these can be identified. The four students, by consistently using the form of answering referred to, would appear to fall clearly within the Piagetian stage of pre-logical in their performance on the particular tasks set.

Response category b) for Q4(i) and category e) for Q4(iv) are related. Five students in the latter category were also in the former category, explaining the concept as "...efficient use of space". An apparent misconception is revealed here, where the common use of 'economic' to mean 'efficient' has been transferred into geography. The students hence understand economic space as efficient use of space; should the use become inefficient, the space is no longer economic space.

With the students exhibiting formal understanding of the concept - categories d) for Q4(i); and f) and g) for Q4(iv) - the relationship between the two tables is not entirely clear. One student who explained space initially for Q4(i) apparently in the formal terms: "... space comprised of economic activity", later gave a concrete response for Q4(iv): "...where economic space becomes uneconomic, it no longer exists". The student is either in conflict as to what he understands by the concept; or understands economic activity as efficient activity. The student, however, was unable to select the most and least representative correctly. Two students and one student respectively from categories Q4(iv) f) and g) gave responses which were categorised as formal for Q4(i). Why the remaining student in category Q4(iv) g) did not give a formal response to Q4(i) is not clear. The fault could lie in the structure of the question, or in the categorisation process. However the student did exhibit formal understanding in being able to select the most and least representative along with the other category Q4(iv) g) student. Only the two students demonstrated the ability to select correctly both the most representative - requiring concrete thinking - and the least representative, which according to Lunnon (1969) requires formal reasoning.

Q2C(i) Social space		
Response types	Response examples	
	a) Did not know.	14
	b) Physical space is the same as social space.	5
Concrete	c) Social space determines social interaction.	5
	d) "If social interaction is large, you get high social space".	1
	e) Social interaction measured in terms of frequency (no reference to social space).	5
Formal	f) Inverse relationship: small social interaction means a large social distance.	7
	g) Social space is influenced by political and economic features as well as just social.	1

The most outstanding aspect of the responses on social space is the large number of students who were not able to answer. On being interviewed, all but one of the fourteen students in the category had heard the concept before, and was familiar with its use. One student commented in the interview that it was "...familiar, but I can't picture at all what it is." The comment is revealing because in wanting to picture social space, the student was indicating the need for a concrete model by which to grasp the concept.

The concept of social space is a formal concept in that its dimensions are variable, and can include mobility, interaction, socio-economic status and family status . Social space can be depicted in terms of a graph but is not reducible to a concrete model. Of the fourteen students who 'did not know', eleven - including the student quoted - exhibited formal thinking on two or less of the Piagetian-type tasks. Hence partial explanation could be found, in that the students had both heard and read about the concept but could not assimilate the meaning, since they may be largely concrete thinkers.

The group of students who understood physical space and social space to be the same thing were asked in the interview to explain further. All students had answered 'True', but explained by saying that since social interaction takes place in the physical surroundings, social space and physical space were the same thing. Their answers were followed up by the question from the interviewer: "Why do you think geographers use the term social space?", to which the students did not commit themselves to an answer.

The third category of response is particularly interesting, although it was not anticipated as a response by the researcher . The response is not a clear explanation and there is an element of tautology similar to that in a statement on space by Hurst (1972): "...it can be maintained that man can, in fact, only define his actions in spatial terms, and that space can only be defined in terms of man's behaviour" (Hurst, 1972, p.23). It may not be chance that two of the five in this category gave responses to the Piagetian-type puzzle which were categorised as IIA, one of whom was quoted as repeating the answer to be explained (viz. Student: "..they can't get there." Interviewer: "Why ...?" Student: "Because they aren't able to").

For category d) the student explained his answer by drawing a hill to represent "high social space". Asked if there were any other ways of representing "high social space", the student was unable to suggest any, nor was he able to suggest how one would assess whether or not social interaction was "high". The student who performed formal thinking on two Piagetian-type tasks appeared to be exhibiting thought patterns similar to the student quoted in category a) in the need to use a concrete model which cannot explain an abstract concept.

As with categories a) to d), the category e) response suggests that the students are thinking in concrete terms regarding the concept of social space. Their response does not relate social interaction to social space which is necessary for an explanation. Instead the students refer to the measure of social interaction and explain how social interaction itself is measured. The students thus indicate affiliation with one of the limitations of a concrete thinker to which Fuller, Karplus and Lawson (1977) refer. The limitation is expressed in the context of physics, where the student "...responds to difficult problems by applying a related but not necessarily correct algorithm" (Fuller, Karplus and Lawson, 1977, p.26). In the present context, the students have responded to the problem by applying a commonly used measure of interaction, which, although related, does not provide a solution in the form of an explanation to the task. Three students in this group answered two Piagetian-type tasks using formal thinking, and the other two demonstrated formal thinking on three Piagetian-type tasks. There is evident inconsistency in the use of formal operations; however, none of the students in the category being discussed were amongst the top two categories of overall performance on Piagetian-type tasks.

The final two categories of responses exhibit an element of formal thinking. The inverse relationship of category f) demonstrates the ability to understand functional relationships, which is one of the characteristics as set out by Piaget. In other words, the students can identify and interpret dependence between abstract variables. It was necessary in the interview to establish whether the students were repeating a rote answer. However, each student was able to explain his response further with ease. The student in the final category explained in the interview that social space is comprised of political, economic, as well as social features. Further, that interaction was only one of many measures of social space, just as kilometres is one of many measures of physical space. The eight students in these two categories all performed formal operational thinking on three or more tasks. The results tend to suggest that the introduction and explanation of concepts such as social space in texts needs to be considered in terms of students' abilities and in relation to the overall order in which concepts are presented.

Q2C (ii) Geographic space		
Response types	Response examples	No. of students
-	a) Did not know.	14
Concrete b) + c)	b) Relief; physical features.	13
	c) "Physical landscape and time"; "distance and time".	3
Formal	d) Social aspects, economic exchange, political environment ...	8

The high proportion of students in category a) is difficult to explain, but the concept was not unfamiliar to the students. One student during the interview commented that "...geographers always seem to talk about the space of all sorts of things, but I think it just all means the same thing." The student seems sceptical about the meaningfulness of space being accompanied by many adjectives. Indeed, such an opinion may be warranted with concepts such as race space (Smith, 1977), taxonomic space (Abler, Adams and Gould, 1972), and elastic space (Thomin and Corbin, 1974), becoming part of a geographic vocabulary. The student's comment is pertinent, particularly if the concepts are not clearly defined.

The reason for the responses in category b) on interviewing the students, seemed to be due to the often-used phrase by people other than geographers: the geography of an area. The phrase is understood as physical features, and the students adopted the meaning for the concept of geographic space. To category b) students, the concept is a concrete one. For students in the remaining c) and d) categories, the concept is understood as an abstract concept encompassing intangible and variable features of a landscape.

The concept requires formal operational thinking. Since many students used the term in their explanations of other concepts in the questionnaire, as anticipated from the results of the pilot study, it is important to establish what students understand by the concept. Three students from category a) used the term in an attempt to explain either social space or economic space.

Q3 Space

i) Briefly explain the concept.
ii) Carefully assess the following statements ...
(a) - (n)
iii) How many dimensions can space have? ...
iv) Name some of these dimensions ...

Concepts of different types of space have been examined, and now Q3 aims to elicit what meaning the student associated with the concept of 'space'. A list of words characterised the responses to Q3(i) rather than a sentence definition. The words ranged from concepts such as area, and land, to abstract concepts including "space is activity". However, on interviewing the students, it was apparent that many were influenced by what was seen in the question following and rarely did a student not re-explain space in a markedly different way from that given in answer to Q3(i). Students were not committed to any one explanation. The changing answers indicate that students depend on the context in which the concept was mentioned from which to devise its meaning. Contextual thinking is not to be discouraged, but a conclusion drawn from the interviews is that although students read and hear the concept used as 'space' and as 'types of space', the students generally seem to be unaware at a conscious level of what they think space is. Q3(ii) aids in summarising the responses given by students.

Q3(ii)

Statements	No. of Students		
	Did not know	True	False
a)... is changeable	1	3	34
b)... can be created	-	31	7
c)... is infinite	3	19	16
d)... can be empty	-	26	12
e)... is a thing	5	15	18
f)... is formed by the presence of one or more things	2	18	18
g)... can be a measure of interaction	2	28	8
h)... is like a container in which activities take place	-	29	9

(cont.)

Statements		No. of students	
	Did not know	True	False
i)... there is only one type of space	1	1	36
j)... a number of types co-exist	1	34	3
k)... is relative	5	28	5
l)... is continuous	3	27	8
m)... is absolute	12	5	21
n)... can act as a force	2	34	2

From the responses to Q3(ii) it is evident that many students have an understanding that recognises space as being interpreted as both relative - b), f), g), j), and k) - and absolute. The sense in which space is referred to in geography literature indicates that both types of space are utilised implicitly (Meyer, 1977). Unless the student understands the differences, and grasp why both types of space are used, he will experience conflict with apparently incompatible concepts. The conflict became evident in the interviews, which will be discussed with reference to Q3(iii) and (iv).

Continuing with reference to Q3(ii), no student who stated either that space was not relative or that space was not absolute, answered the rest of the questions in that understanding. The inconsistency could mean that students did not understand what absolute or relative meant, or were guessing. If the student understood that space was not absolute (as twenty one students did), he should have answered, false to d), e), h), i), l) and m). No student exhibited consistent answering in this regard. The reason revealed in interviews is that students are unsure about many of the possible attributes of space of any kind. In the interview, the student was asked to further elaborate on his explanation to Q3(i). In the light of the response and answers to Q3(ii), the student was asked to explain what he understood by 'dimensions'. A table of responses to the number of dimensions and how a dimension was understood is revealing.

No. of Dimensions	Examples of Dimensions	No. of students
Did not know		6
3	a) area	2
	b) length/horizontal, breadth, height/vertical	9
4	c) air space/vertical, outer space, horizontal space.	1
	d) could only name length, breadth, height.	2
	e) length, breadth, height and time.	4
5+	f) width, length, breadth, height, diagonal, different angles.	10
	g) length, breadth, height, time, cost, socio-economic factors.	4

From the table there is obvious misunderstanding as to what can constitute a dimension. Those students who 'did not know' were asked in the interview the same question, in case the questionnaire had contributed to confusion. In all six cases, none of the students could give an answer. A point of extreme importance here is that none of the six were B.Sc. students, and only one had done geography at school. Such a finding highlights the need to strengthen introductory courses in first year in order to reach such students. Also emphasised is the need to be cautious as to what to assume students already know. A danger lies also with those students in group f) who, in being able to name five or more dimensions, did not realise that they did not know what a dimension was. Also, as can be seen from the answers tabulated, the students were not aware that width and breadth were the same. Excerpts from interviews further illustrate problem areas.

Interviewer: I see you've suggested that there are three dimensions. Could you give some examples again of these?

Student: Length, breadth, height or vertical, horizontal, diagonal.

Interviewer: Diagonal?

Student: Yes, (draws the three axes of three-dimensional space, and points to the third axis as 'diagonal').

Interviewer: And how many dimensions does a sphere have?

Student: One.

Interviewer: And a cube?

Student:	Three ... because you can see them.
Interviewer:	And you can't see them in a sphere?
Student:	No, because whatever way you turn it (the sphere), it looks the same.
Interviewer:	And what about a pin cushion - a sphere with lots of pins sticking out at all angles?
Student:	That would have as many dimensions as there would be pins.

The above student seemed unaware that his answers were contradictory in terms of the number of dimensions. The student also shows the need to be able to "see" the dimensions in order for them to exist, which is characteristic of concrete operational thinking.

Interviewer:	I see you've indicated that space can have five dimensions. You've given a couple of examples: length, height/vertical, horizontal ... Could you give more examples?
Student:	Yes ... (picks up pen and thinks) ... you'd have this (draws two axes for two-dimensional space -a); then you'd have another one - b) ...Well, then you'd eventually get all angles like this c), except into the page and sticking out as well.

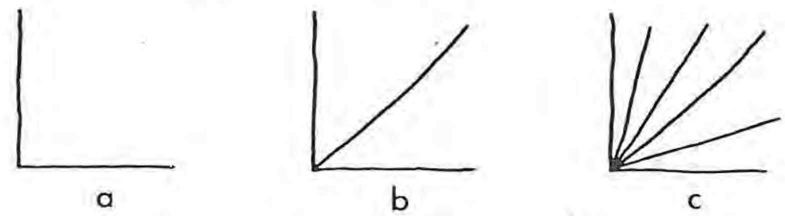


Figure 10: One student's responses to questions on dimension.

Interviewer:	And how many dimensions would that show?
Student:	As many as you like.
Interviewer:	Would you see socio-economic status as a dimension?
Student:	No, it's not measurable.
Interviewer:	I see you've indicated that there are five plus dimensions... Could you name some of these?
Another student:	Well, besides the basic sides of a cube, it depends on how big the area is.
Interviewer:	How big the area is?
Student:	Yes, because if the area is bigger, it's got more dimensions.
Interviewer:	Can you suggest what some of the dimensions would be?
Student:	You could get lots of vertical dimensions, or lots of horizontals.

The above interviews illustrate the need for an interview to supplement a questionnaire, since the answer of five or more dimensions could be misunderstood by the researcher as an advanced response. The above students were unaware that they misunderstood the concept

Some of the students indicate a realisation that space is complex and can have five or more dimensions, but clearly do not understand what a three dimensional space can consist of. Although the above results were not anticipated, it was expected that students who thought in terms of a three-dimensional physical space would be unable to grasp adequately concepts of space such as economic space and relative distance. Economic space and distance decay are concepts utilising an n-dimensional space, and embodying characteristics of space which include space as being changeable, able to be created, formed by the presence of things, and of which any number of spaces can exist. Three of the students in category b) in the above table can be traced by their responses in the questionnaire along the lines just described. Although only a third of the total number are in category b), pointing out such a pattern is invaluable for identifying a problem and for remedial action.

The tracing of one group of students' thinking is described above, and underlines the value and importance of establishing what it is that students are unable to master, and the need to discover possible origins of the problems. One of the aims of concept analysis is to reveal students' problem areas, and is thus an essential part of the education process.

The null hypothesis that students in the sample will not have misunderstandings regarding the selected concepts of space in geography, can be rejected on the basis that for all concepts tested, there were categories of students wh had misunderstanding of the concepts. There were students who had an inadequat understanding or no understanding of the concepts. The findings are important since, as revealed in the literature survey, the concepts of space are rarely defined or explained. Also of importance is the need to express in the results what can be assumed as general knowledge - e.g. dimensions - and what cannot. The question is thereby raised: can concept analysis in geography be used for more effective learning and teaching, and for encouraging transition from concrete to formal thinking? This question will be addressed in the final chapter.

2. Review and implications

Students do have problems regarding concepts of space in geography, and many students appear to be unaware at a conscious level of what their understanding of space is. The lack of awareness can be dangerous in that space could then become whatever one made it in each situation. The exercise then becomes that of "...coining space phrases" as one student verbalised it. A similar phenomenon can be found in geographic literature as referred to in the section on concepts of space, yet the existence of debate as to what space is, indicates that the changing meanings of concepts of space are not acceptable amongst geographers. Also, a concept which is given differing meanings in varied contexts by different authors or teachers does not aid in cumulative research, particularly when the meaning attributed to the concept is not made explicit. An example of a possible contributing factor may be useful here.

A text used by the sample of students tested was by Kolars and Nystuen (1974). The concept of geographic space is mentioned at an early stage of the book, but no definition is given: "The corresponding patterns on these two maps indicate a strong correlation in geographic space between high growth rates and low incomes" (Kolars and Nystuen, 1974, p.4). The student is left to guess as to the exact meaning of geographic space. The concept is again mentioned at a later stage in the context of the geographer's concern, explaining the approach to space, but still no definition is given: "Geographers do not consider space as an object or condition which exists in itself. The space which concerns us is defined functionally by the relationship between things. It is the nature of this geometric and topological relationship that forms the basis for the study of geographic space" (Kolars and Nystuen, 1974, p.14). Further reference to the question will be made in the analysis of responses to questions of space. What is being defined as the space with which geographers are concerned is an abstract concept, requiring formal operational thinking in order to understand it. The space is not static, changing with changes in functional relationships. The researcher suggests that the description of the nature of such a space as being geometric and topological is misleading. Topological space is limited to each object being considered in isolation. It is with projective and Euclidean space that objects are considered as part of a whole system with relationships between the objects (Piaget and Inhelder, 1956). Further, geometric relationships require the student to be able to perform operations on the basis of an understanding of topological, projective and Euclidean spaces (Piaget and Inhelder, 1956). If the researchers' suggestion is correct it would seem Kolars and Nystuen (1974) have over-simplified the concept, which could explain why the concept was introduced at such an early stage in the text. A further example lies with the social space.

The concept of social space is included in basic undergraduate text books, one of which is Abler, Adams and Gould (1972) who introduce the concept first on page eighty four, but it is only explained on page 171. Besides the lag between the introduction and explanation of the concept, it is introduced at a relatively early stage for an abstract concept in a book of over five hundred pages. The organisation of concepts and order of their introduction in text books could be a factor in contributing to the misunderstanding of concepts.

The above is only one possible contributing factor to some of the students' difficulties associated with concepts of space. Nevertheless it illustrates adequately an absence of a reliable form of feedback for the students, by which they can readjust their understanding and use of the concepts.

It is also apparent that many of the concepts of space require formal operational thinking for understanding. Yet many of the students tested are unable to consistently think formally. Hence unless these factors are realised, and unless effort is made to encourage the transition from concrete to formal thinking, many of the concepts of space being introduced to the student do not match his ability. An outstanding example of a formal concept being taught to students at an early stage is that of scale. The concept is taught at school, and is introduced early in the students' first year of geography at university. Although the need for students to understand such an important concept in geography is clear, it is not clear that teachers and text books take into account the level of difficulty of the concept.

A further reason for misunderstanding a concept can originate in a particular understanding a student has regarding a prerequisite concept. Such a phenomenon is evident in the example of the students' understanding of distance which is prerequisite for economic space. A concrete understanding of distance, limiting it to measures of physical distance (e.g. kilometres), prevents the student being able to understand the formal concept of economic space. The terminal concept requires a formal concept of distance which includes the less visible forms of distance, measurable in terms of, for example, social aspects, perception, cost and time.

The few examples above indicate the scope for exploring and revealing possible origins of students' conceptual problems, which also can reasonably be said for teachers' conceptual problems. The study of a sample of Rhodes University geography students will be reviewed in the final chapter in terms of the results and with regard to the application of concept analysis in geography. Problems encountered in the study will be discussed and possible modifications in some areas suggested. The chapter will draw together the examination of concept analysis, and its application to concepts of space in geography.

D. OVERVIEW

As a result of a review of literature and informal discussion with geography students, it became apparent that much of the literature does not define in explicit terms the concepts of space used in the literature, and that students experience difficulty in understanding the concepts. To investigate the problem, a concept of space was selected for analysis - the concept of economic space - and related concepts were identified. Concept analysis was then applied.

The concept analysis required a concept hierarchy to be postulated and a questionnaire formed which examined students' conceptual ability as evidenced in their performance on the questions. Hypotheses were then formed on the basis of Piagetian and Gagnéan theory, as well as on the evidence of the concept problem manifested in the literature. To test the hypotheses the questionnaire and interview results were examined closely applying statistical and qualitative techniques of analyses.

The hypotheses based on Piagetian theory were as follows.

H I : There will be students in the sample unable to exhibit formal operational thinking in the tasks on an aspect of topological space.

H II : There will be students in the sample unable to exhibit formal operational thinking in the task on aspects of projective space.

HIII : There will be students in the sample unable to exhibit formal operational thinking in the tasks on aspects transitional between projective and Euclidean space.

H IV : There will be students in the sample unable to exhibit formal operational thinking on the puzzle testing abstract reasoning ability.

Hypotheses I - IV were accepted. There is an evident lack of formal operational thinking by the sample of students exhibited by responses to the set tasks. The concepts of space in geography such as economic space, social space, relative distance and relative location are evidently formal concepts. Understanding of these concepts required formal thinking. Only students who were capable of formal reasoning on three, four or five Piagetian-type tasks were able to exhibit adequate understanding of the terminal concept of economic space.

The hypothesis regarding students'misunderstanding of concepts of space was accepted.

H V : Students in the sample will have misunderstandings regarding the selected concepts of space in geography.

Each concept tested elicited a number of responses which revealed misunderstandings. The interviews in conjunction with the questionnaire exposed patterns of thinking by the individual students. The interview also served to overcome some of the disadvantages of a paper and pencil test, i.e. enabling reasoning to be explored, ambiguities to be checked, and in some cases served as learning experiences for the students.

Hypotheses on the basis of Gagné's work were formed for each of the seven pairs of concepts tested:

H VI - XII : Those students with skill II are totally included among those with skill I.

All hypothesised hierarchical connections could not be rejected on the basis of White and Clark's (1973) test. Problem areas in the technique relevant to the case study and to non-exact science concepts were outlined and areas for possible modification suggested. The subjective analysis of responses on different concept tasks in the hierarchy brought to the fore patterns of thinking and misunderstandings which were interesting, and warrant more than casual concern. Individuals' patterns of thinking and possible origins of misunderstanding were able to be traced. However, for group trends to become clearer more needs to be known about the relationships between the concepts in the hierarchy; and the questionnaire requires revising to distinguish more clearly between students' abilities.

Gagné's (1962) results in hierarchical research implied that if hierarchies are representative of the sequence of learning, then hierarchies are valuable tools by which to improve learning and teaching. However, content cannot be considered apart from the learners' abilities. Piaget provides a framework which is a clear and useful guide to identifying individuals' abilities. A dual-theoretical approach of Piaget and Gagné provides a more holistic tool in concept analysis by which to identify and understand problems associated with teaching and learning concepts.

The results of the case study reveal the essential nature of the research and issues a challenge to all involved in geography teaching to reappraise their methods and assumptions; and to those involved in learning to be aware of conflict between their understanding of a concept and information offered by texts and teachers, and to attempt to establish why the conflict exists. It is evident that there is a need for an empirically well-established tool to be available for all geography teachers to listen closely to the learner.

Although problems in the analysis still exist, further research would improve the tool for application specifically for the non-exact science concepts. The final chapter offers more detail in terms of the problems, prospects and perspectives of concept research in a review of the study as a whole.

CHAPTER SIX

RETROSPECT AND PROSPECT

Concept analysis has been explored in its theory and empirically, in a search for a paradigm for concept research in geography. Theories of cognitive development and learning such as those of Piaget and Gagné have contributed to discoveries made regarding students' abilities and instruction methods in the learning and teaching of concepts.

Despite various refinements made in the implementing of the theories and in techniques of analysis, numerous problems remain. The case study utilised the experience of past research and both yielded results which have implications of some import, and outlined a possible paradigm for concept research in geography along with difficulties encountered. Review and evaluation of the study as a whole will indicate a future possible direction to be taken in concept analysis research in geography.

A critical examination of the theories of Piaget and Gagné as used in concept analysis revealed many warnings which need to be borne in mind for future research. There is also a complexity of factors which influence cognitive development, and often there exists an apparent inconsistency in a students' thinking - being able to think using formal operations on some tasks and only concrete operations on others. Both the complexity of factors and the apparent inconsistency make identification of causal factors difficult, and render tentative any predictions of ability based on tests of a small range of tasks. Finally, Piaget suggested age ranges for the levels of development which the results of many studies have not supported. However, it is necessary to see beyond the limitations listed, since they do not disprove Piaget's theory but rather serve as directives in the use of his theory.

The issues of 'learning sequence' is a complicated one as Sakmyser (1974) recognised. Gagné's theory represents the initiating force for hierarchy research, with much subsequent research using his theory as a basis (Anderson, 1972). Some problems associated with learning sequences include the initial bias, in that the concepts selected for hierarchy validation can either be accepted or rejected, but there is no method for indicating which concepts have been excluded. Hierarchy validation tests are still undergoing research in order to be refined, simplified and made more reliable.

The case study for selected concepts of space used in geography adopted the duel theoretical base of Gagné and Piaget due to the advantage of their complementarity. Hypotheses were based on the theories, and on the concepts of space tested. There are a number of ways in which the case study could have been improved. Although the small sample was sufficient for the exploratory study, a larger sample would enable greater weight to be given to conclusions drawn, and less obvious trends would become clear. A longitudinal study would display developments in students' thinking over a period of time, which would be useful as a measure of the effectiveness of learning and teaching which had taken place. However, before large scale studies are launched, further inquiry is needed into methods and techniques in order to stream-line concept analysis to form an acceptable research strategy which would make large scale studies highly productive. The present case study however, did achieve a number of objectives.

The case study revealed the conceptual abilities prevalent in a second year university class. Knowledge of the students' abilities is essential for development of reasoning to be encouraged and for effective teaching methods to be designed. Attention has been given to geography students' abilities. The study serves both as a warning that it cannot be assumed that second year students will understand many of the formal geographical concepts; and as an affirmation that a focus on students' abilities is warranted. Future research needs to work towards producing tests which are empirically well-established for geographical concepts, and which every teacher can administer. Although trends may not be established for small classes, the specific ability of each student is valuable knowledge in helping overcome learning difficulties, and in indicating how the student can be stimulated to use the abilities he already has.

The case study also illustrated some of the types of misunderstandings which exist in the sample, and which could be encountered amongst other students. A number of reasons were suggested for the misunderstandings. In many cases the problem seemed to lie in a mis-match between conceptual ability of the students and the conceptual demand made by the concept. One outstanding example was that of scale. Scale is necessary for many tasks of problem-solving in geography. Scale is being taught at high schools, and is one of the first concepts taught at Rhodes University in first year. The concept demands formal operational thinking, and yet many students in second year university still do not think with formal operations, and struggle to grasp the concept fully. With such an essential concept which needs to be taught at an early stage in a geography course due to the structure of geography, the answer need not be to cease teaching the concept until, for example, third year. The answer to wrong 'X' is not no 'X', but right 'X' : The answer to incorrect teaching of a concept need not be to cease teaching it, but to improve the method of instruction. In such a case, a suggested improvement could involve the establishment of the following three steps : students' conceptual abilities; what the students already understood - or misunderstood - the concept to be; and what the prerequisite concepts were that needed to be understood before the concept of scale could be grasped. The research strategy in Fig. 4 could be followed.

Research is still needed on each of the steps, and particularly on how the transition from concrete to formal thinking of students can be encouraged. However, research discoveries at present are sufficient for limited but useful studies, including studies comprised of the above three steps. An outcome of importance of these studies is that they would contribute to answering a question posed by Fuller, Karplus, and Lawson (1977). The question was put to physicists, but applies here: What can geographers do to make the study of geography "...less of a slave to the ... structure of the discipline, and more a servant to the development of reasoning?" (Fuller, Karplus, and Lawson, 1977, p.28). For all geographers to be able to participate in the development of reasoning in students, a research paradigm needs to be identified.

The present study has been a search for a paradigm for concept analysis research in 'non-exact' geographical concepts. The study has outlined a possible paradigm and offered a questionnaire which could be used in different universities.

The relevance of concept analysis and the need for research toward strengthening methodologies has been indicated. Development of the research requires an awareness that there is much as yet unknown - for example, the role of intuition, and whether there is a level of concept understanding which is not elicited by the type of tests administered. Since what is not known, cannot be tested, any paradigm proposed cannot be based on the assumption of perfect knowledge and must ideally leave room for the unknown to be discovered. Hence researchers need to work on the basis of what is known, but not to the exclusion of what is not known.

For future research, Feyerabend (1975) issues a warning relevant to concept analysis for 'non-exact' sciences where levels of understanding are particularly difficult to identify. Feyerabend (1975) warns that progress in research is often inhibited by a lack of freedom to introduce the unknown or contradictory which enables discoveries to be made as a result of a counter-inductive research procedure. With so much as yet unknown in examination of 'non-exact' concepts, there is ample room for exploratory studies. However, Feyerabend's (1975) completely anarchistic approach may not be helpful, since past and present research form a framework within which discoveries of the unknown can be made.

The future of geography depends on the philosophical examination of fundamental concepts, and effective learning and teaching depends on research utilising learning theories. Concept analysis is therefore important, and is an attempt to research the basic concepts of a discipline, and to bridge the gap between what is taught and what is understood. Studies thus far have indicated both the need and the potential for concept analysis research. The present study reveals a similar need and potential for 'non-exact' science concepts. Awareness of the potential expressed in exploratory studies in all disciplines is imperative, since within research discoveries of the past, lies the presence of future research.

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APPENDIX A

RHODES UNIVERSITY

GEOGRAPHY DEPARTMENT

CONFIDENTIAL

Male	☐
Female	☐
B.A.	☐
B.Sc.	☐
Other (e.g. B.A.,Phys.Ed., LPTC)	☐
Matric geography at school	☐
Std. 8 geography at school	☐
No geography at high school	☐

Name: ....

Code: ☐☐☐

Academic year: ☐ 1st ☐ 2nd ☐ 3rd

Age: .... Years.

The questionnaire is aimed at testing your understanding of certain geographical concepts. Concepts describe a way in which the mind structures particular experiences, such that these experiences become classified and evoke a similar response amongst all people.

Read the questions carefully and answer as best as you can. If you cannot answer a question or part of a question, leave it and go on and try the next. Please do not guess.

SECTION I

This section contains a number of questions about concepts often used in human geography.

1. Briefly explain what you understand by the following concepts:

(i) Location (e.g. of an industry)

....

....

(ii) Distance

....

....

In what units can distance be measured?

....

(iii) Interaction

....

....

In what ways can interaction be measured?

....

(iv) Proximity

....

....

Name some factors which influence proximity.

....

(v) Accessibility

....

....

Name some factors which determine accessibility.

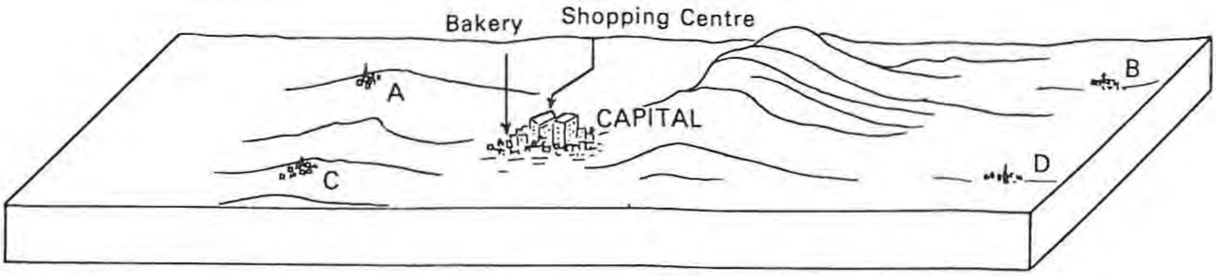
....

(vi) Distance decay

....

....

2. The diagram of a model landscape below shows small towns A, B, C and D, and a bakery situated in the shopping centre of a large town called Capital, west of a small mountain range.



A. These questions concern only towns A, B and Capital.

(i) The demand for bread at A is the same as the demand for bread at B. The baker is prepared to make deliveries to place A but not to place B. In <u>explaining</u> the baker's delivery patterns, which one of the following considerations would you feel to be the most important. Place a cross in the appropriate block.

(a) Likelihood of delivery is reduced with increased distance from the bakery

(b) Distance has a friction effect on travelling (friction of distance)

(c) Cost and distance involved, or

(d) Cost and time involved.

(ii) In what units should the baker have measured the distance between the bakery and place A? Place a cross in the appropriate block.

(a) Kms

(b) Kms plus altitude covered

(c) Cost and time of travel

(d) Kms plus cost and time of travel

(e) Kms^2

B. This question concerns the four towns A, B, C and D.
People have been commuting by car between these towns for some years, but recently a bus service has been started. Carefully read the clues about possible bus trips at present.
The bus trips may be direct or include stops and bus changes in a town. When a bus trip is possible it can be made in either direction between the towns.

First clue: People can go by bus between towns C & D.

Second clue: People cannot go by bus between towns A & B.

Use these clues to answer Question (i). Do not read the next clue yet.

(i) Can people go by bus between towns B and D?

Yes ☐
No ☐
Cannot tell from the 2 clues ☐

Please explain your answer. ....

....

Third clue: (Do not change your answer to question 1 now!)

People can go by bus between towns B and D.
Use all three clues to answer questions (ii) and (iii).

(ii) Can people go by bus between towns B and C?

Yes ☐
No ☐
Cannot tell from the 3 clues ☐

Please explain your answer. ....

....

(iii) Can people go by bus between towns A and C?

Yes ☐
No ☐
Cannot tell from the 3 clues ☐

Please explain your answer. ....

....

C. Using the above diagram:

(i) Assess the following statement:

Just as the physical space between places A and B can be measured in terms of physical distance (e.g. kms), so the social space between A and B can be measured in terms of social interaction between the places.

True	False

Briefly explain your answer:

....

....

(ii) List what you think would constitute the attributes of geographic space in the above diagram:

....

....

(iii) Scale is the ratio between map distance and the actual ground distance that the map represents. If the scale of the above model landscape is 1:100 000, what would be the scale if the landscape was reproduced to half its present size?

....

3. For the concept of space:

(i) Briefly explain the concept:

....

....

(ii) Carefully assess the following statements:

	True	False
(a) Space is unchangeable		
(b) Space can be created		
(c) Space is infinite		
(d) Space can be empty		
(e) Space is a thing		
(f) Space is formed by the presence of one or more objects		
(g) Space can be a measure of interaction		
(h) Space is like a container in which activities take place		
(i) There is only one type of space		
(j) A number of types of space co-exist		
(k) Space is relative		
(l) Space is continuous		
(m) Space is absolute		
(n) Space can act as a force		

(iii) How many dimensions can space have?

(a) 2	
(b) 3	
(c) 4	
(d) 5+	

(iv) Name some of these dimensions:

....

....

4. For the concept of economic space:

(i) Briefly explain the concept

....

....

(ii) Choose the two situations which are <u>most</u> representative of the concept of economic space, and the two which are the <u>least</u> representative. Place a cross in the appropriate blocks.

	Two most representative	Two least representative
(a) Space occupied by an industrial site		
(b) Area worthy of resource extraction		
(c) Area defined by economic exchange		
(d) A network of communications		
(e) Area occupied by public gardens		
(f) The site of a commercial banking company		

(iii) Assess the following statement:

Economic space can be expressed as a surface in the same way as a physical space can be expressed as a physical landscape surface.

True	False

(iv) Briefly explain your answer:

....

....

SECTION II

This section is concerned with more general concepts of space.
Place a cross in the appropriate box.

____ (straight line ten centimetres in length)

1. With reference to the straight line drawn above,
   (i) Imagine a line half its length.
   (ii) Imagine a line half the length of (i).
   (iii) If you were to carry on cutting up this line continually, you would eventually be left with:

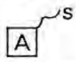
   a) nothing at all
   b) a small line
   c) a point with the shape of a line
   d) a point without the shape of a line
   e) none of the above.

2.

If the triangle above was continually reduced or shrunk, you would eventually be left with:

   a) nothing at all
   b) a point the shape of the triangle
   c) a very small line
   d) a point with no particular shape
   e) a point with a slight peak

3.

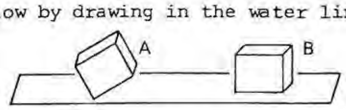


'A' above shows a piece of cardboard with an attached string 'S'. If 'A' was held by the string and spun by twisting 'S', what would be the shape described by the perimeter of the cardboard?

   a) cube 
   b) cube tilted 45^{o} 
   c) 3-sided pyramid 
   d) 
   e) 

4. The diagram below shows a closed water tank, one-fourth filled with water.

Complete the diagram below by drawing in the water line in both A and B.



5. Refer back to the sketch of the model landscape in Section I.
The sketch is viewed from the south. In the space below, redraw this model landscape as it would be viewed from the north.