Keele University

THE INFLUENCE OF SELECTED COGNITIVE STYLES ON LEARNING BEHAVIOUR

A thesis submitted for the degree of Doctor of Philosophy of the University of Keele

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ABSTRACT

The study reported in this thesis was designed to determine whether the leanings of students on a few selected cognitive styles have an effect on their learning from two different modes of instruction, viz. the discovery and the expository modes. The cognitive styles chosen for the study were:-

i) Field independence-field dependence

ii) Conceptualisation styles

iii) Conceptual differentiation

iv) Convergency-divergency

v) Reflectivity-impulsivity

In Phase I the research issue was examined with respect to five short decoding/serial tasks, whilst in Phase II a series of four specially developed chemistry learning units were employed. The study of the effect(s) of cognitive styles on learning behaviour was extended to an examination of the association of students' cognitive styles leanings with their preference for different instructional modes. This examination was carried out with respect to two constructs i.e., the relative ease/difficulty and enjoyment/dislike of the instructional modes.

For the data analysis, the following statistical procedures were used: analyses of variance, analyses of covariance and t-tests. In general, the results indicate that the field independence/field dependence style and the inferential conceptualisation style interact significantly with learning behaviour. Field independent students have an advantage over their counterparts in learning situations which require the analysis and synthesis of information. This advantage remains statistically

significant even after partialling out the IQ effect. With respect to the inferential conceptualisation style, the high inferential thinkers seem to have an advantage over the low inferential thinkers in concept formulation tasks via the discovery mode.

No significant interaction was found between achievement from the learning tasks and the other cognitive styles examined (conceptual differentiation, convergency-divergency, and reflectivity-impulsivity).

The examination of the effect of cognitive styles on the preference for learning types revealed that cognitive styles leanings not only affect students' learning behaviour and achievement, but also their attitude towards the different modes of instruction and learning. Field independent students and high inferential thinkers perceive learning by discovery to be relatively more enjoyable and satisfying than learning from exposition. In relation to the ease/difficulty of the instructional modes divergent thinkers and high conceptual differentiators perceive learning by discovery to be relatively more difficult than learning from exposition.

Throughout the study, theoretical analyses were made of the possible effects or interaction of students cognitive styles leanings on their learning behaviour and their attitude towards or perception of learning from different instructional modes. The results of these theoretical considerations are presented in the thesis, as appropriate, and compared with the empirical findings. In general, the latter are reconcilable with the theoretical arguments presented.

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CHAPTER 1 COGNITIVE STYLES AND LEARNING

1.0 INTRODUCTION

For a number of years, educationists and teachers have tried to find adequate bases on which to make decisions about how learning and teaching can be organised in the best and most effective way. In attempting the foregoing, people have looked mainly towards psychology and related fields although, more recently, there has also developed much concern for the investigation of the instructional processes, partly through classroom-based interaction studies of the Flander's type and partly through approaches which fall within the realm of the aptitude-treatment-interaction (ATI) model. As far as the psychological area is concerned, much interest has centred on the exploration of the Piagetian theory as forming a basis for decision-making about instruction, with another "interest area" also attracting attention; that of the application of Gagnéan theory about learning hierarchies in the design of instruction.

Recently, interest has emerged in another area of psychology as providing potentially a basis for decision making about instruction: this is the area of "differential" psychology which seeks to explore the differences between people and the implication of the latter for teaching and learning. Differences in abilities, aptitudes, motivations, etc., in students have long been recognised to exist and often been taken into consideration in the design of teaching. Differentiation according to abilities, usually measured by IQ tests, has been commonplace in the schools, likewise, differentiation according to aptitudes if and where these could be measured, has also occasionally been used. The rationale underlying these kinds of differentiation is to match particular teaching approaches with particular qualities/characteristics of the learner. Not unnaturally, educationists look for further qualities on the basis of which decisions about the design of instruction can be taken. For example, Shayer (1980) has recently suggested that even at the secondary level, instruction should be in line with the developmental level of students in Piagetian terms. Therefore, there is a general interest in looking for qualities and characteristics within students which allow teachers to make sensible differentiations in relation to qualities and characteristics which have a bearing on the effectiveness of learning and teaching presented to students.

1.1 THE DIMENSION OF INDIVIDUAL DIFFERENCES AND LEARNING

The search for and study of characteristics which allow for differentiation between persons, in the psychological sense, falls within the area of differential psychology. As has already been mentioned, differential psychology is concerned with the exploration of differences between persons and, as far as possible, with an examination of the consequences of such differences for this behaviour in learning and teaching situations, as well as in social situations.

Individual differences have traditionally been associated with IQ and IQ biases and various other ability-related factors. These individual differences are used in educational practices such as in the selection of students for courses, the streaming of students in schools, the selection of curricula and teaching approaches for different groups of students. But, over the last twenty or so years a new dimension has been brought into the purview of individual differences; this is the dimension of cognitive styles. Cognitive styles have hitherto remained relatively unexplored in relation to their importance for teaching and learning although a number of notable researches have been published and despite the fact that a number of major research groups (for example, the Brooklyn group headed by H. A. Witkin, the Menninger group led by

P. S. Holzman and R. W. Gardner and the Fels group headed by J. Kagan) have explored the area of cognitive styles. Researches as they are thought to be relevant to the topic under discussion will be reviewed in details in Chapter 2.

Although the nature of cognitive styles, including their definition, will be explored in detail in Chapter 2 of this thesis, some brief characterisation of the concept of cognitive styles has to be given here in order to allow further discussion of the topic. For the purpose of this discussion, cognitive styles may be thought of as a person's "characteristic modes of perceiving, remembering, thinking and problem-solving." As this definition implies, cognitive styles do by and large not express cognitive abilities. They are, therefore, different from notions such as IQ and IQ biases which are, of course, ability-related measures. Nevertheless, because cognitive styles can have a bearing on the way in which information is perceived, or the way in which information is analysed and integrated into a student's overall cognitive framework, they may under certain circumstances be expected to have a bearing on the student's learning itself. For example, a particular cognitive style, expressing a student's leaning towards either a highly analytical style of thinking or non-analytical (global) thinking mode, may well have a bearing on his ability to abstract from an array of stimuli presented to him, a conglomerate of stimuli which forms a concept. Therefore, a cognitive style like this, may significantly influence the student's concept attainment. Satterley and Brimer (1971:302), in relation to work in this area, have stated

> "potentially, research into cognitive styles is as profitable to the guidance of learning as studies of any other individual differences in cognition."

A point which has to be made at this particular juncture, is that as far as the area of cognitive styles is concerned many different dimensions have been identified and that it would not be appropriate to claim that each and everyone of these styles should have a significant bearing on learning. This particular aspect is further discussed in Chapter 2.

1.2 COGNITIVE STYLES AND INSTRUCTIONAL STRATEGIES

If one accepts that cognitive styles can influence and have a bearing on student's learning, it is not unreasonable to predict and hypothesise that a similar interaction may exist between cognitive styles and instructional strategies. After all, instructional strategies are means whereby learning on the part of students is meant to be fostered. Consequently, one may argue that different instructional strategies represent different means and different conditions whereby learning is to take place. Thus, cognitive styles orientations may, via the learning element, interact with instructional strategies. Some research , for example, that of Satterley and Telfer (1979), indicates very convincingly that such interactions exist.

Of particular interest in the context of science teaching is the instructional strategy conventionally referred to as discovery learning. Curriculum projects carried out over the last twenty or so years, have invariably advocated that students should engage in their own independent discovery, albeit under the guidance of the teacher, and that learning resulting from a discovery-oriented instructional approach produces significant advantages over learning from procedures from which the discovery element is absent and where information or items to be learned are simply stated and communicated by the teacher or text in the form of exposition (expository approach).

A considerable amount of research has been done over a long period of time to examine the proposition implicit in what has just been said, namely that discovery learning invariably is advantageous compared with expository teaching. Some of these researches will be referred to in Chapter 2, but it may be mentioned here briefly that evidence, in so far as it has resulted from expirical studies, is highly controversial and contradictory. There is no overwhelming evidence available to suggest that discovery learning does necessarily have educational advantages over expository teaching methods. Findings of this particular nature have invariably been derived from broadly-based studies in which particular characteristics of students have only rarely been taken into consideration. In cases where the differential effects of different instructional procedures on learning have been examined (for example, in relation to high, medium and low ability levels), some interactions between instructional approaches and ability levels have been reported. For example, in one study Rowlett (1966) found that the discovery procedure tended to be more suitable for low ability students and that the high ability students benefited comparatively more from expository teaching approaches. This already indicates that individual differences (in this case, in generalised ability) can have a significant bearing on the effectiveness of different teaching and learning strategies. It is thus not unreasonable to hypothesise that individual differences in cognitive styles may equally interact with instructional procedures. As Kogan (1971:292), in a review of the works on cognitive styles and their educational implication, has suggested:

> "though the practical pay off of cognitive style research are still quite meagre for the teacher, the promise of future rewards is strongly indicated if energy and imagination are applied to the task."

1.3 THE PRESENT RESEARCH PROBLEM

The present research study was conceived against the background just outlined. It is a study in which the effects of a number of different cognitive styles on learning from two different instructional modes was investigated. The instructional modes chosen were the discovery procedure and the expository procedure. The cognitive styles chosen for the study were as follows:-

(i) Field independence/field dependence - this entails a tendency to experience items as discrete from their backgrounds and reflects an ability to overcome the influence of an embedded context; that is a stylistic quality which (in its field independent form) expresses an analytical, in contrast to a global, way of perceiving the environment (Witkin et al. 1974).

(ii) Conceptualisation styles - expressing consistency in the utilisation of particular conceptualisation approaches as bases for forming concepts. Among these is the routine use of a relational theme when sorting stimuli, as opposed to the use of descriptive attributes or the assignment of stimuli to a broader class (Kagan et al. 1963).

(iii) Conceptual differentiation - expressing individual differences in the tendency to categorise perceived similarities and differences among stimuli in terms of either many differentiated concepts or few broad concepts (Gardner and Schoen, 1962).

(iv) Convergency/divergency - which relates to individual's relative reliance upon thinking which is pointed towards logical conclusion and uniquely correct or conventionally best outcomes in problem-solving, as opposed to thinking which is pointed towards variety and quantity of relevant output (Guilford 1967; Hudson 1966).

(v) Reflectivity/impulsivity - indicative of an individual's tendency to analyse sets of stimuli cautiously and reflect on the adequacy of a solution before reporting, or to report solution quickly with minimal consideration for its possible accuracy. (Kagan et al. 1964).

The above five cognitive styles were selected from a much wider range of cognitive styles described in the literature because it was thought that these in particular could have a bearing on the way in which students with different cognitive styles leanings behaved in learning situation, especially in those exploying the discovery mode of instruction. The expository mode of instruction was also investigated in equivalent situations with respect to these cognitive styles, largely to provide a reference basis. It is, of course, necessary to develop specific hypotheses as to why the cognitive styles chosen should effect learning behaviour in discovery and/or expository situation, and of what kind these interactions might be. This is a topic which will also be discussed in Chapter 2.

Also, it was recognised at the outset that the effect of cognitive styles on learning outcome, i.e. on students' learning achievement in the main, would be only one facet to pay attention to and that the question of whether students with different cognitive styles orientation have a preference for different types of learning, also merited consideration. In consequence, the study was extended to take account of this particular facet also.

1.4 BRIEF OUTLINE OF THE RESEARCH

As has been mentioned, five cognitive styles were chosen as the basis of the investigation plus two teaching approaches, namely the discovery and the expository mode of instruction. These two teaching approaches were used in two different contexts. In the first, a series of exercises was used which had previously been reported in the literature as having been used in comparative studies of the effectiveness of discovery learning and expository learning. These exercises involved unscrambling words, decoding words, completion of letter series and number series and sum of odd-numbers series, and were of relatively brief duration of up to approximately twenty to thirty minutes learning time each. Five such exercises were used, and they were presented in both the discovery and expository mode so that comparison could be made. This part of the study is, for the purpose of this communication, referred to as the 'Phase I study'.

In the second context, a further examination of the same above problem was undertaken in relation to a set of chemistry learning tasks which were specifically developed for the purpose of this research. These chemistry learning tasks were concerned with particular aspects of the fourth year Nuffield Chemistry programme, dealing with aspects of Periodic Table, and the stoichiometry and formulae of compounds (more details will be given in Chapter 3). These learning units required four double periods for their administration and once again were developed in a discovery format and an expository format.

It should be pointed out here that in all cases an attempt was made to eliminate the possible effect of the variability of teachers on teaching, this was achieved by the use of a programmed self-instructional approach throughout. Details about the learning exercises are given in Chapter 3.

For the examination of whether students with different cognitive styles orientation have a preference for different types of learning, a 'preference for learning types' inventory was developed and administered. Details of the inventory are given in Chapter 3. Also, in addition to the cognitive styles tests, the AH4 general intelligence test was administered as an ancillary test. The reason for this follows from the observation by several researchers that certain cognitive styles measures correlate lowly but significantly with IQ. Therefore, in order to be able to judge the actual effect of a cognitive style upon students' learning outcomes, it is necessary to "partial" out any IQ effects on the style.

Figure 1.1 summarises the overall research design of this study.

1.5 STRUCTURE OF THE THESIS

Chapter 2 of this thesis presents a detailed description of the characteristics of cognitive styles in general and also reviews the relevant studies relating to the cognitive styles and instructional modes selected for this investigation. It further includes statements of the possible effects of each of the cognitive style on learning from the two modes of instruction.

Chapter 3 gives a detailed account of the research methodology used; in particular, it presents a description of the tests and the learning tasks used, and of the population and the administrative procedure adopted for the study.

In Part I of Chapter 4, the performance of the various tests is analysed, poor items identified and decisions made about them. In Part II, the associations between the various cognitive styles measures and also between the cognitive styles and IQ measures are examined.

Chapters 5 and 6 relate the results of the present study with respect to the relationship between cognitive styles and learning behaviour. In Chapter 5 the results of the Phase I study are reported, which concern the relationship between cognitive styles and learning outcomes from the short decoding and serial tasks. Chapter 6 reports the results of the influence of the cognitive styles on chemistry learning.

Chapter 7 reports the results of the investigation of the influence of cognitive styles on students' perception of ease/difficulty and enjoyment/dislike of the two learning approaches (discovery/expository).

Finally, Chapter 8 summarises the findings of the study, discusses the limitations and shortcomings, and suggests possibilities for further work in this area.

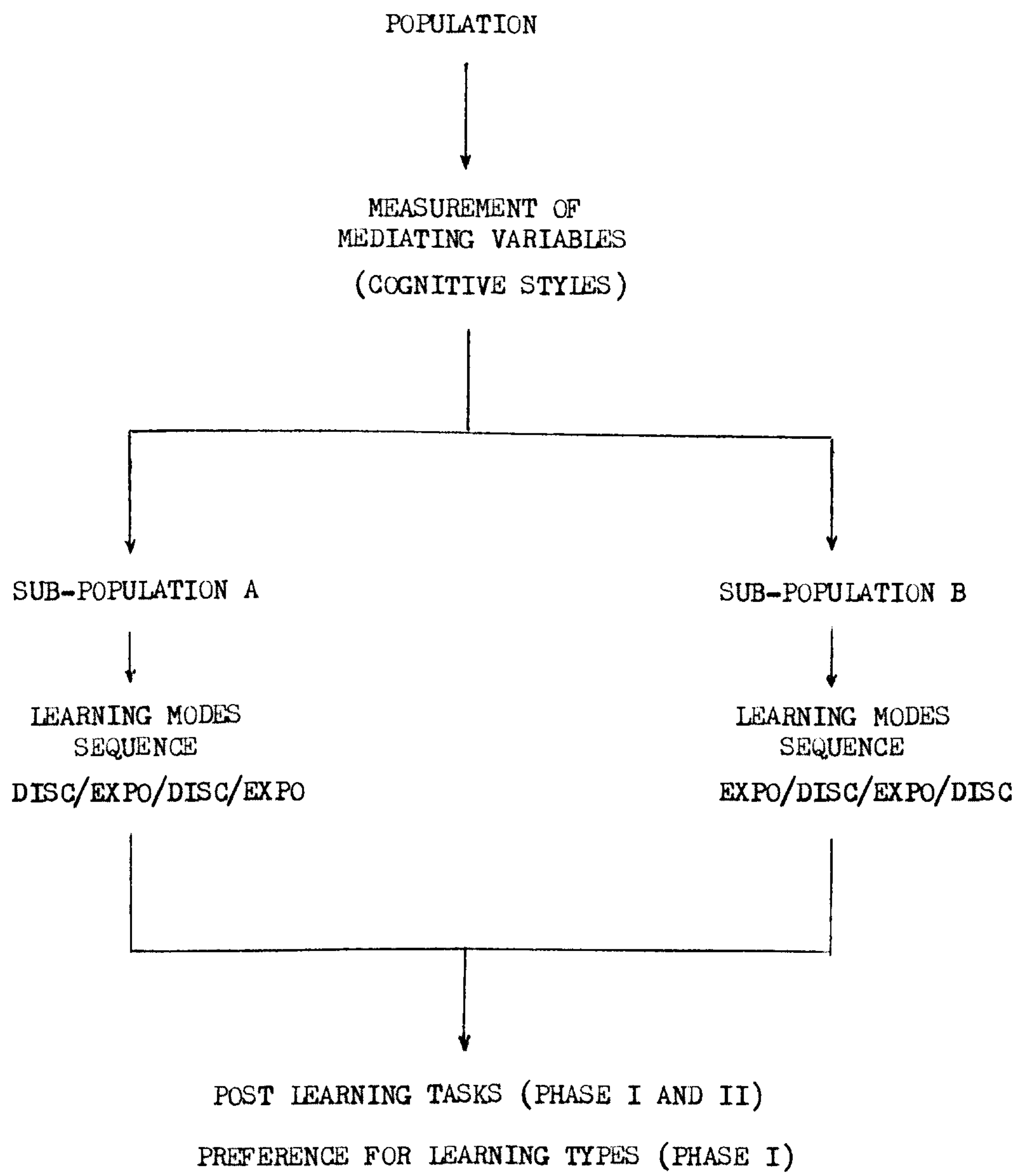

Figure 1.1 Research Design of the Study

CHAPTER 2 REVIEW OF RELEVANT LITERATURE

2.0 INTRODUCTION

In this chapter, a review of the research literature is presented in so far as it relates to the general topic of this study, i.e., the relationship between cognitive styles and learning under different conditions of instruction. In the first part of this chapter, the cognitive styles theme is explored, initially with reference to cognitive styles in general and thereafter with reference to the cognitive styles dimensions selected for this study. The second part is concerned with a review of researches into the discovery-expository dimension of instruction.

2.1 THE CONCEPT OF COGNITIVE STYLES

The concept of cognitive styles stems from the work in the area of differential psychology which is concerned with the study of differences in human behaviour. The method of study of human behaviour in terms of styles involves the study of each of the psychological levels at which an individual functions. When the psychological functions appear to take place in a relatively stable fashion within individuals, the label of styles has been ascribed to describe them. Witkin et al. (1971:11) use the term 'style' in relation to psychological functioning to denote "a consistent tendency to function at a more or less differentiated level in many situations."

Early work in this field was mainly concerned with individual differences in the perceptual characteristics, and was carried out by psychologists like Cartell and Jastrow at the turn of the century and by psychologists like Thurstone and Guildford during the 1940's. Since then, the greatest amount of research into cognitive styles has been closely connected with three groups of researchers: the Brooklyn group headed by H. A. Witkin, the Menninger group led by P.S. Holzman and R. W. Gardner, and the Fels Institute group headed by J. Kagan. In addition to these, other investigators like S. Messick, N. Kogan and D. R. Goodenough have also made major contributions to the study of individual differences. Out of their works has now emerged a cognitive style theory, on the basis of which cognitive behaviour can be partialled into numerous inter-related, self-consistent modes of intellectual and perceptual functioning. Theoretical views concerning the nature of cognitive styles will now be considered.

Witkin et. al. (1971:14) view cognitive style as a subset of perceptual and intellectual functioning. They argue that embodied in each cognitive style are two processes, of which one is concerned with the perception of information from external stimuli, whilst the second concerns the characteristic way in which that information is processed by the individual. Thus, Witkin et al. define cognitive styles as "the characteristic self-consistent modes of functioning which individuals show in their perceptual and intellectual activities." Messick (1970:188) has advanced a slightly more specific definition of cognitive styles as "information processing habits which represent a person's typical mode of perceiving, thinking, remembering and problem solving," whilst Kogan (1971:244) refers to cognitive styles as "distinctive ways of apprehending, sorting, transforming and utilizing information" by individuals.

In the general sense, the above definitions are essentially equivalent to one another, but it is worth noting that they do not, by and large, refer to levels of cognitive abilities. The emphasis in cognitive styles is on the manner and form of cognition, i.e., the way in which the behaviour occurs and not on the level of accomplishment. Besides, cognitive styles are also thought of as being bipolar in contrast to the general unipolar nature of abilities. Witkin et al. (1977:16) suggest that:

> "This characteristic (bipolarity of cognitive styles) is of importance in distinguishing cognitive styles from intelligence and other ability dimensions. To have more of an ability is better than to have less of it. With cognitive styles, on the other hand, each pole has adaptive value under specified circumstances and so may be judged positively in relation to those circumstances."

Another major way in which cognitive styles are said to differ from abilities is in their breadth of coverage. Abilities tend to be specific to a particular domain of content and function, whereas cognitive styles in contrast appear to cut across domains. Messick (1976:9) has suggested that cognitive styles

> "appear to serve as high level heuristics that organise lower level strategies, operations and propensities - often including abilities - in such complex sequential processes as problem solving and learning."

But it must be remembered that these two constructs, cognitive styles and abilities are not as it were diametrical opposites without any overlaps. Messick (1976:11), in his discussion of the distinctions between cognitive styles and abilities, claims that:

> "these distinctions are not so sharply etched; there are varying degrees of difference and overlap between particular cognitive styles and abilities in terms of both conception and measurement."

This relationship between cognitive styles and abilities or IQ will be discussed later in this chapter with respect to the cognitive styles selected for investigation in the present study.

In view of the (marginal) overlap between cognitive styles and abilities and the somewhat vague nature of the definitions of cognitive styles given in the literature, it is appropriate at this point to indicate the notion of cognitive styles that has been adopted for the present study. As has been stated in Chapter 1, this study is concerned with an examination of the relationship between cognitive styles and learning behaviour. Therefore, in the context of this examination, cognitive style is taken as the tendency of individuals to use in a regular or habitual way a developed or acquired capacity, strategy or preference in information-processing which are encountered in the learning process.

2.2 RANGE AND VARIETY OF COGNITIVE STYLES

The greatest interest in the field of individual differences in cognition by many groups of individuals with different theoretical leanings has led to the introduction of a diversity of labels to describe what has now come to be called cognitive styles. We now find in literature, besides the term cognitive styles, such terms as cognitive control principles, cognitive strategies, information processing modes, learning styles, etc. Kogan (1971:245) thinks that

> "These conceptual distinctions are more a matter of differences in the theoretical orientation of the investigator than of the differences in the phenomena."

Hence, no sharp distinctions are made between them. In 1970, Messick made the first attempt to list and describe the various cognitive constructs labelled styles, controls, strategies etc. Messick's list contains nine separate cognitive constructs; these are identified and briefly described in Table 2.1. The table also gives the names of the researchers initially describing the cognitive styles.

In 1976 Messick modified his listing of cognitive styles. For example, he divided the conceptualisation construct into a conceptual differentiation style and a set of conceptualising styles (relational, descriptive and inferential); furthermore, he added new cognitive styles dimensions, e.g. risk taking versus cautiousness which refer to a consistent

TABLE 2.1 COGNITIVE STYLES AND THEIR MODES OF ASSESSMENT

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1. Field independence versus field dependence - refers to an analytical, in contrast to a global way of perceiving (which) entails a tendency to experience items as discrete from their background and reflects ability to overcome the influence of an embedded context (Witkin et al. 1974).

   Three assessment procedures are used, the Rod and Frame test, the Body Adjustment test and the Embedded Figures test. These tests require the subject to specifically differentiate either the task object or himself from the surrounding environment.

2. Scanning - a dimension of individual differences in the extensiveness and intensity of attention deployment, leading to individual variations in vividness of experience and span of awareness (Gardner and Long 1962; Holzman 1966).

   This style is assessed by a size-estimation task. The subject is asked to adjust a circular light patch until it appears equal in size to a disc held in the hand or projected on the wall.

3. Breadth of Categorizing - consistent preferences for broad inclusiveness, in establishing the acceptable range of specified categories (Pettigrew 1958).

   This style is assessed by means of a questionnaire. The questionnaire consists of items which specify the average values of specific categories like length of dogs, width of road and the subject is required to select extreme members of the categories (such as longest, shortest) from an array of multiple choice alternatives presented.

4. Conceptualisation Styles - individual differences in the tendencies to categorize perceived similarities and differences among stimuli in terms of many differentiated concepts, which is a dimension called conceptual differentiation, as well as consistencies in the utilisation of particular conceptualizing approaches as basis for forming concepts - such as the routine use in concept-formation of thematic or functional relations among stimuli as opposed to the use of descriptive attributes or the inference of class membership (Gardner and Schoen 1962; Kagan et al. 1963).

   Conceptualization styles are assessed by the Object Sorting test and the Conceptual Preference test. Basically in these tests the subject is required to group objects that go together in some way and indicate a reason for grouping them together. The number of groups formed in the Object Sorting test reflects a person's leaning on the conceptual differentiation construct while the reasons given for grouping two of the three objects in Conceptual Preference test indicates the preference for a particular conceptualization approach.

5. <u>Cognitive Complexity versus Simplicity</u> - individual differences in the tendency to construe the world and particularly the world of social behaviour in a multi-dimensional and discriminating way (Kelly 1955; Bieri 1961).

This cognitive style is assessed by the Role Construct Repertory test. The most commonly used variation of the test consists of a grid with ten role titles (e.g. mother, friend, disliked teacher) along one axis and ten bipolar constructs such as outgoing-shy, calm-excitable and interesting-dull on the other (Bieri et al. 1966). The subject is required to rate each role type on each construct on a six point scale. The cognitive complexity/simplicity score is obtained by comparing the rating given one role on a particular construct to ratings given that role on the other constructs.

6. <u>Reflectivity versus Impulsivity</u> - individual consistencies in the speed with which hypothesis are selected and information is processed, with impulsive subjects tending to offer the first answer that occurs to them, even though it is frequently incorrect, and reflective subjects tending to ponder various possibilities before deciding (Kagan et al. 1964).

The Matching Familiar Figures procedure is used as the basic index of this style. The items in the test consists of a standard stimulus (e.g. leaf, table, lamp) and six variants, one of which is identical to the standard. The subject is required to choose the variant which is exactly identical to the standard. Response time and correctness of the choice constitute the main variables.

7. <u>Levelling versus Sharpening</u> - refers to reliable individual variations in assimulation in memory. Subjects at a levelling extreme tend to blur similar memories and to merge perceived objects or events with similar but not identical events recalled from previous experiences. Sharpeners at the other extreme are less prone to confuse similar objects and by contrast, may even judge the present to be less similar to the past than is actually the case (Holzman 1954; Gardner et al. 1959).

The Schematizing test is the standard procedure for assessing this style. In this test the subject is required to make judgement on a series of squares of increasing area and scored in terms of the number of correct placements in a sequence.

8. <u>Constricted versus flexible control</u> - individual differences in susceptibility to distraction and cognitive interference (Klein 1954; Gardner et al. 1959).

The most favoured assessment procedure is the Stoop Colour-Word Inference test. The test consists of colour words. The subjects task is to name the colour of the ink in which the colour words are printed (e.g. the word red printed in blue ink).

9. <u>Tolerance for incongruous or unrealistic experiences</u> - a dimension of differential willingness to accept perceptions at variance with conventional experience (Klein et al. 1962).

One of the procedures used for assessing this trait is the experience of apparent movement. The subject is shown a pair of stimuli and by increasing and decreasing alternation rate of projection illusion of movements are produces. Subject's readiness to accept and report the experiences at variance with reality gives an indication of his leaning on this cognitive construct.

This table has been adapted from Chapter 6, "The Criterion Problem in Evaluation of instruction: Assessing possible, Not Just Intended, Outcomes" by Samuel Messick, from the Evaluation of Instruction: Issues and Problems. Edited by M. C. Wittrock and David E. Wiley by Holt, Rinehart and Winston Inc. 1970.

individual differences in a person's willingness to take chances to achieve desired goals as opposed to a tendency to seek certainty and to avoid exposure to risky situations; sensory modality preferences which refer to individual consistencies in relative reliance upon the different sensory modalities available for experiencing the world; convergency versus divergency which represents an individual's relative reliance upon convergent thinking as contrasted to divergent thinking in terms of quality and quantity of relevant output. In his modified listing, Messick gives nineteen different cognitive style constructs, but some of these have attracted very little attention since their inception.

2.3 CLASSIFICATION OF COGNITIVE STYLES

It can be seen from the array of cognitive styles listed above that cognitive styles manifest themselves in different types of behaviour. Some convey "special" skills to persons, for example in recognising simple figures in a complex background, in the estimation of size, or in overcoming distractions. Others appear to be concerned merely with an expression of preferences without involving ability-related skills; 'breadth of categorisation' would be an example of this type of style, as would be conceptualisation styles and cognitive preferences reported, for example, by Kempa and co-workers (Kempa and Dubé 1973, Kempa and McGough 1978). In view of the diversity in the range of cognitive styles, some form of classification seems desirable. A first attempt in this respect was made by Kogan (1973) in terms of the respective distances of the styles from the construct of ability. He distinguished between three types of cognitive style. These are briefly characterised in Table 2.2 and illustrated by reference to some of the cognitive styles dimensions given by Messick's 1976 listing.

In a later review of cognitive styles, Kogan (1976) has discussed the

TABLE 2.2 KOGAN'S CLASSIFICATION OF COGNITIVE STYLES

TYPE	CHARACTERISTICS AND EXAMPLES
1	- refers to styles which indicate an ability to perform certain tasks with performance judged against a standard. For example, an individual who is field independent is better able to locate elements embedded in the surrounding context than a field dependent person. (Hence, type 1 is close to the ability domain). Other styles which appear to have the same characteristics are scanning, levelling-sharpening, constricted versus flexible control, reflection-impulsivity (as measured by error scores).
2	- the focus here is on the type of strategy employed in a problem situation. Though there is no a more accurate or a less accurate approach, a value distinction is imposed upon the dimension such that performance at one extreme is considered superior to performance at the other. For example, with the Kagan, Moss and Sigel's analytical/non-analytical categorization styles, the analytical style receives greater approval than the non-analytical style. Other styles which may be included in type 2 class are the complexity/simplicity cognitive style, reflectivity-impulsivity (latency score), convergency-divergency, and conceptual preference styles.
3	- relates to preferred modes of cognitive functioning that do not test particular ability or strategy per se. No value judgement are placed upon the kind of response and they are most purely stylistic in nature. Kogan has cited Pettigrew's Breadth of Categorisation, that is, setting of broad or narrow limits when provided with a measure of central tendency for a category, as an example of this type of cognitive style. Other cognitive styles that appears to belong to this type are conceptual differentiation and sensory modality preference.

shortcomings which he saw in his classification scheme, especially with reference to type 3 class of cognitive styles. In his classification system, the classification of a cognitive style as a type 2 style depends on a greater value being attached to one pole of the cognitive style than to the opposite pole. This value attribution is made either on purely theoretical ground, for example by postulating that one pole may be associated with a developmentally more advanced stage than the other, or it is based on observed empirical correlates of the style with achievement. Membership of type 3 class depends, by comparison, on the "value neutral" nature of the cognitive style in question. The styles which have been placed within this class are there because research evidence has so far not shown any consistent pattern of co-relates that suggests one pole is advantageous over the other. However, this does not rule out the possibility of further research outcomes requiring type 3 cognitive styles to be reclassified as type 2. Thus, the basis of distinguishing between type 2 and type 3 cognitive styles is a weak one, from a theoretical point of view. It is conceivable that this differentiation may have to be abandoned as more empirical evidence is generated. This would result in two broad categories of cognitive styles remaining, i.e. ability-related and strategy/preference-related cognitive styles. This broad classification would not be of much help in classifying cognitive styles in terms of their likely educational importance and implication, as it would not offer any guidance as to which cognitive styles would have some bearing on learning and teaching and which would not.

2.4 AN ALTERNATIVE ATTEMPT AT CLASSIFYING COGNITIVE STYLES

Within the field of education, the importance of cognitive styles must be seen in relation to the ways in which instruction can be modified or designed to take advantage of the natural inclination of students in learning. Hence, a classification of the cognitive styles in relation to instructional/learning process would be a desirable first step for a systematic attempt to investigate the interaction or influence of cognitive styles on instructional modes and learning behaviour.

To classify the cognitive styles in relation to learning behaviour, some model of the learning process is needed. For the present purpose, a simple four-phase model is proposed which is summarised in Figure 2.1.

It must be pointed out that the breakdown of the learning process into the phases suggested in Figure 2.1, is largely a matter of convenience, and that it is not possible to make any rigorous distinction between these stages. They do overlap and "run into each other." Nevertheless, the breakdown appears meaningful and acceptable for the present purpose.

The cognitive styles themselves may conveniently be divided into two main categories:

i) cognitive styles which affect performance because of an intellectual predisposition, as e.g. field independence/ field dependence and conceptualisation styles.

ii) cognitive styles which affect performance because of a more 'personality-orientated' predisposition, as for example, reflectivity-impulsivity and scanning behaviour.

On the basis of this classification and the above learning model, it is now possible to classify the cognitive styles into a 2 (nature of cognitive style) x 4 (learning phases) categorisation scheme. For example, field independence-field dependence is basically a perceptual trait due to the intellectual predisposition of the person. Therefore, it would not be unreasonable to suggest that it would have an influential effect on the way in which the presented information is perceived.

Learning phases		"Events" relating to the learning process
1. Information reception/perception	→	stimuli presented are perceived in different ways as the result of students' internal characteristics or personality.
↓		
2. Information organisation/selection	→	stimuli perceived are organised and/or selected in accordance with pre-existing disposition and leanings.
↓		
3. Information transformation	→	sets of stimuli, in their perceived form or pre-selected arrangement, are "interacted" with existing cognitive structure, leading a modification of the latter and the integration of information into the learner's cognitive structure.
↓		
4. Information storage	→	integration of information into long-term memory structure. Students' internal characteristics and pre-dispositions may affect this integration process.

Figure 2.1 A Theoretical Learning Model

Conceptualising styles, likewise, depend on the intellectual predisposition of a person, but relate to his leaning towards a particular type of conceptualisation (i.e., relational, descriptive or inferential); therefore, they would have their greatest influence in the selection and organisation phase of learning. Table 2.3 shows the classification of twelve cognitive styles on the present classification system.

2.5 SELECTION OF COGNITIVE STYLES FOR THE STUDY

From the array of 12 cognitive styles which can be associated with the learning process and fitted into the model, a group of five cognitive styles was selected for the present study. These five cognitive styles are:-

i) Field independence-field dependence
ii) Conceptualisation styles
iii) Conceptual differentiation
iv) Convergency-divergency
v) Reflectivity-impulsivity

The reasons for the selection of these particular cognitive styles are that (a) the styles seem to have a major bearing on learning/instruction and (b) the procedures for their measurement are reasonably well documented, and the relevant tests are fairly readily available. It must be pointed out at this point that the selection of cognitive styles for classroom investigation is severely restricted by the complex nature of the measuring procedures involved in the assessment of students' leaning on some of the cognitive style constructs. Kogan (1971), in his review of cognitive styles and their educational implications, found that with the exception of few cognitive styles like field independence/field dependence, conceptualisation styles and reflectivity-impulsivity, explicit investigations of the influence of cognitive styles on classroom

TABLE 2.3 CLASSIFICATION OF COGNITIVE STYLES BASED ON THEIR POSSIBLE INFLUENCE AT THE DIFFERENT LEARNING PHASES

LEARNING PHASE	COGNITIVE STYLES AFFECTING LEARNING BECAUSE OF	
	INTELLECTUAL PREDISPOSITION	PERSONALITY-ORIENTED PREDISPOSITION
1. Information reception/perception	(i) Field independence vs. field dependence (ii) Field articulation	(i) Scanning (ii) Constricted vs. flexible
2. Information organisation/selection	(i) Breadth of categorisation (ii) Conceptual differentiation (iii) Conceptualising styles (iv) Convergency-divergency	(i) Reflectivity vs. impulsivity (ii) Risk taking vs. cautiousness
3. Information transformation	(i) Cognitive complexity vs. simplicity	
4. Information storage	(i) Levelling vs. sharpening	

learning and instructional problems are extremely limited or non-existent.

Of the five cognitive styles selected, the field independence-field dependence style may be expected to influence the perception and reception of information during the learning process, whilst the other four styles may have a bearing on the way in which students select and organise information for the purpose of concept formulation or concept attainment during the learning process.

A detailed review of the literature was undertaken to conceptualise each of the five selected cognitive styles and their possible influence on learning when the learning material are presented in two different instructional modes namely discovery mode and expository mode. This review is reported in the following sections with respect to each of the five selected cognitive styles.

2.6 REVIEW OF STUDIES RELATING TO THE SELECTED COGNITIVE STYLES

2.61 Field independence-field dependence

a) General aspects: characteristics, measurement and correlations with other measures

As stated earlier this cognitive construct was first identified by Witkin and co-workers as a perceptual trait. Basically, this cognitive style involves an analytical (in contrast to a global way) of perceiving the environment. For example, when presented with a simple geometric figure embedded in a complex figure, the analytic or field independent person has relatively little difficulty in abstracting the simple figure from its complex surroundings, whereas the global or field dependent person encounters difficulties in such a task. Therefore, a field independent person may be described as one who is able to overcome the effects of distracting background elements when attempting to abstract aspects of a particular situation. He would also have the skill or tendency to impose structure on situations lacking it. Field dependent persons, in contrast, would be relatively unable to free themselves from the distracting elements of the field and/or environment, and also would having the tendency not to structure things or events when such structure is not apparent. Also, in the domain of social behaviour marked differences have been observed between field dependent and field independent persons. Field dependent persons are found to be more attentive to and make use of the prevailing social frames of reference to guide their behaviour. This makes them more susceptible to external influences (Witkin et al. 1974).

Correlational data on two longtitudinal groups indicate high levels of stability in the relative positions of individuals on the field independence-field dependence dimension (Witkin et al. 1967). As far as absolute positions on the field independence/dependence spectrum over time are concerned, both the cross-sectional and longtitudinal results cited by Witkin et al. show progressive increases in field independence upto the age of about 16 years, but individuals maintain their position relative to others.

As has already been mentioned, three assessment procedures have been used to measure field independence. These are the Rod and Frame test (RFT), the Body Adjustment test (BAT) and the Embedded Figures test (EFT). (Witkin et al. 1974, 1977). In the RFT, the subject's task is to adjust the rod to a position where he perceives it as upright while the frame around it remained at its initial position of tilt. In the BAT, the object of perception is the body of the subject rather than an external object, such as the rod in the RFT and the issue is how people determine the position of the body itself in space. The subject is seated in a chair and tilted and he is then asked to adjust the chair to a position, where he experiences it as upright. In the EFT, the subject is shown a simple figure, it is removed and he is shown a complex figure with the directive to locate the simple figure within it. All these tests give a quantitive indication of the extent to which the surrounding organised field influences a person's perception of an element within it. Inter-correlations among the three tests indicate that significant relationship exists among them. The correlations are generally in the range of 0.30 to 0.60 (Witkin et al. 1974). Of the three tests, the Embedded Figures test is the one that is now most extensively used as a measure of the field independence-field dependence trait. A number of versions of this test suitable both for children and adolescents has been developed and used in cognitive styles researches (French, Ekstrom and Price 1963; Gardner et al. 1960; Goodenough and Eagle 1963; Jackson et al. 1964; Kempa and Cox 1976; Satterly and Telfer 1979; Witkin et al. 1971). Some of these versions have been designed for group adminstration. Two of these were selected for the present study, namely the Satterly and Telfer version and the Kempa and Cox version of the Embedded Figures test. A detailed description of these tests is given in Chapter 3.

The question of the relationship between field independence-field dependence and IQ has been extensively studied. A number of the studies show a positive relationship between field independence and intelligence. Witkin et al. (1974) report a significant correlation of moderate magnitude between field independence and total IQ derived from Standford-Binet and WISC. Goodenough and Karp (1961) carried out a factor analysis of all the relevant WISC measures and found some indication that performance on measures of field independence is related to performance in the WISC subtests of Picture-completion, Block-design and Object Assembly. Goldstein and Blackman (1978), from their review of 20 studies, state that there is a general consistent indication that the various measure of field independence are related to various measures of both verbal and performance intelligence. The correlations between field independence and intelligence are mostly in the range from r = 0.40 to 0.60. In the light of this, it must be suggested that a statistical control of intelligence may be necessary when relating field independence to other variables. In the present study, this was done in connection with the analysis of the influence of field independence-field dependence on chemistry learning by discovery and expository mode.

b) <u>Field independence-field dependence and learning behaviour</u>

Studies on the role of field independence/dependence on students' learning behaviours have used both the cognitive and social characters associated with the style to conceptualise the relationship between learning behaviour and this cognitive style. Relatively field dependent persons have been found to be selectively attentive to social aspects of the surrounding (Fitzgibbons, Goldberger and Eagle 1965; Messick and Darmin 1964) and because of this orientation, tend to be better at learning materials with a social orientation or bias. Ruble and Nakamura (1972) gave children three concept-attainment problems. They found that field dependent children did better than the field independent children in the problem where the social cue alone was relevant.

Another aspect of learning behaviour for which a great deal of evidence is now available from experimental situations, is the relationship between field dependence-field independence and the effects of various kinds of reinforcements. It is found that field independent persons tend to learn more than field dependent persons under conditions of intrinsic motivation (Fitz 1971; Paclisanu 1970; Steinfeld 1973) but this difference disappears when external rewards for learning are introduced. Extrinsic rewards, both of a material and a social kind, seem to have a significant effect on field dependent persons. This is not surprising as field dependent persons rely more on external referents for self-definition than do field independent persons. (Witkin et al. 1977).

Bolocofsky (1975) studied the effect of classroom competition on the learning performance of field independent and field dependent students. Tenth grade students classified into field dependent/field independent according to their performance in the Group Embedded Figures test, were administrated reading comprehension tasks. A significant interaction between field dependence and competitive motivation was found. Field dependent subjects increased their performance significantly when competing, while field independent subjects exhibited only a slight and non-significant change.

In the realm of the cognitive aspect of field independence/dependence character, studies have focused on the mediating influence of this cognitive style on students' learning behaviour in terms of achievement, especially with respect to concept learning.

Nebelkopf and Drayer (1973) studied the shape of learning curves of field independent and field dependent subjects in a concept attainment task. The learning curves of field dependent subjects showed a gradual improvement from trial to trial, indicating a "spectator approach" on their part. By comparison, the learning curves of field independent subjects showed no significant change until the concept was identified indicating a "hypothesis-testing approach." Also, it was found that field dependent persons are dominated by salient attributes of the stimulus and tend to ignore the non-salient cues in constructing hypotheses about the concept. By contrast, field independent persons tend to sample more fully the range of attributes and treat these more objectively for concept definition (Dickstein 1968; Goodenough 1976). These findings have important significance to educators because of the contemporary demand that students should learn concepts, rather than facts. In general, it is thought that this can be achieved by the discovery instructional mode, but the foregoing findings suggest that field dependent learners would be disadvantaged under such learning conditions.

This leads to another area of enquiry: that of the influence of the field independence/dependence style on learning outcomes, especially under different instructional strategies. It would appear that learners with a field independent disposition, because of their articulated character, are likely to analyse and impose structure on a random array of information and thus provide organisation as an aid to their learning, whilst field dependent learners, because of the <u>in</u>ability to abstract and impose structure on random information, are likely to leave things as they are. Therefore, field dependent subjects are likely to encounter difficulties in the learning of materials which lack inherent structure or which have not been adequately prestructured by the teacher. This has great educational implications because most modern curricula, especially in the field of science and mathematics, have designed learning materials in such a form that the learner himself is required to seek information, organise and abstract the pattern or generalisation contained in them. In such situations, it would appear that field dependent subjects might be greatly disadvantaged. This point has been at the centre of a number of studies using different subject matter content and different instructional modes.

Koran et al. (1971) examined the development of analytic questioning skill among graduate student teachers in training. They used two treatments to provide trainees to ask more penetrating questions when analysing problems in class discussion. In the video-modelling (VM) treatment, a videotape showed a master teacher performing the required skill. For the written modelling (WM) treatment, the same master teacher performance was presented as a typed transcript. The criterion was the number of analytic question each trainee asked in the subsequent ten-minute micro-teaching lessons. Koran and co-workers found that the written modelling was best for field independent students, whilst the video-modelling treatment proved better for field dependent students. Snow (1976) interprets this by assuming that in video-modelling the key stimuli are clearly indicated to the learner in the video presentation while in the word modelling the learner must abstract them from a typed transcript. Thus, field independence or analytic ability is needed in WM but not in VM.

Annis (1979), studied the effect of field independence-dependence on learning passage organisation. Half the students in her sample received the organised version of an 80 sentence passage entitled "Evolution of the brain," and the other half received a scrambled passage. In the organised version of the passage, the material of high informational importance was more salient than in the randomly recorded, unorganised passage. It was found that field independent student scored better than field dependent students on test items concerning the meaning of the entire learning passage, regardless of whether the passage was organised or unorganised. However, the effect of cognitive style on material of low informational importance was not significant. It is likely that field independent students score better on high structural importance items because they actively analyse and abstract general principles and mediating concepts from the passage, whereas field dependent students are more likely to use a 'spectator approach' to learning, relying on the characteristics of the learning task itself rather than analysing or imposing their own structure on it.

Satterly and Telfer (1979) studied the interaction between field independence and the effects of advance organisers in learning. The key issue of the study was the expectation that advance organisers would enhance the performance of field dependent, but not of field independent subjects in coding task requiring more than simple rote-learning. This should be so because advance organisers are essentially an aid to the structuring of material in the learner's mind and field dependent person display far more limited structuring ability than do field independent persons. Three instructional conditions were used in the study

1. Lessons on word structure without advance organiser
2. Advance organiser plus lessons on word structure
3. Advance organiser plus lessons on word structure plus specific references at fixed points in the lesson to the organising properties of the advance organiser.

The subjects were stratefied into three levels of field independence and the groups were compared in recall and transfer. As expected the field independent learners accomplished the learning task significantly better than the field dependent counterparts in the absence of advance organisers. The use of advance organisers with specific reference to its organising properties enhanced the score of field dependent learners but had no significant influence on the scores of the field independent group. The differences were maintained even after the variance attributable to general intelligence was removed.

Grieve and Davis (1971) found the amount of knowledge students acquired by different teaching methods tended to be related to their cognitive style. In their study, a comparison was made of the amount of geography learned with either an expository or discovery method of teaching by extremely field dependent and extremely field independent ninth grade children. For the discovery method, they reported that "verbalisation of generalisation being taught was delayed until the end of the instructional sequence," whereas in the expository method "verbalisation of the required generalisation was the initial step of the instructional sequence." They found that the more field dependence the pupil, the more likely was he to benefit from discovery instruction. They explained this somewhat unexpected finding in terms of learning in the discovery method taking place through the interaction with the teachers, which represents a context congenial to the social orientation of the more field dependent student. However, it must be stated that the conceptualisation of discovery-based instruction in this study was not what is normally termed "discovery learning." The students are not independently involved in the discovery of the generalisation. Rather, the teacher, through a process of questioning and cueing, helped the class as a whole to arrive at the generalisation at the end of the instructional sequence. Hence, it is not really appropriate to say that the field dependent students perform better than field independent students under discovery instructional mode.

McLeod and Adam (1979a) tested the hypothesis that student with a field independence cognitive style would learn more about numeration system if they had minimum guidance and maximum opportunity for discovery through the use of manipulative material. Field dependent students, in turn, were expected to perform best with maximum guidance and symbolic treatment. The topic presented was addition and subtraction in bases other than ten. Data gathered on 46 prospective elementary school teachers who had been randomly assigned to the two treatment groups, supported these hypotheses. However, in another study by the same authors (McLeod and Adam 1979b), using a geometric topic, no significant interactions were found between field independence and treatments that differed in level of guidance.

Douglass and Kahle (1978) tested the hypothesis that field dependent student would reach a higher level of achievement with a deductive sequence of instruction than would be expected with an inductive sequence of instruction, and that field independent learner would experience greater success in inductive sets of material than would be expected if deductive materials were used for instruction. Instructional material in Mendelian genetics and probability were developed in an audio-tutorial, self-paced mastery format. The subjects were 627 High School Biology students. The dependent variables were post-test score and gain score. When all subjects were considered, there was no significant interaction between cognitive style and the sequence of the instructional material. However, when only those subjects were considered who were more than one standard deviation from the mean field dependence-independence score, the interaction of cognitive style and instructional sequence was significant. The nature of the treatment - aptitude interaction was such that the field independent subjects experienced greater success with the inductive material, and the field dependent subjects experienced greater success with the deductive material.

Shymansky and Yore (1980), in a recent study have focused on how field independence-field dependence interacts with three types of discovery teaching strategy (semi-deductive, structured inductive and hypothetico-deductive) in influencing student achievement in science as measured by performance on quizzes of science processes and content. They found no significant difference between the groups with respect to the structured inductive and hypothetic-deductive strategy. However, the field independent subjects performed significantly better on the semi-deductive strategy than did field dependent subjects. According to the experimenters, the semi-deductive treatment had the least inherent structure built into its design: only the content structure characteristic of the physical sciences guided the strategy. Thus, it would appear that the low structure design in the semi-deductive treatment placed an organisational demand on the field dependent subjects that they were ill-equipped to handle. On the other hand, the structured inductive and hypothetic-deductive strategies contained greater degrees of inherent structure, which decreased the self-structuring required of the individual students; thus the field dependent students apparently were not significantly disadvantaged.

Ritchy and Lashier (1981) examined the possible interactions between the field independence/dependence cognitive style and two modes of teaching in terms of students' achievement. The two modes of instruction investigated were the guided approach and self-study approach to the learning of anatomical information. The achievement test consisted of an in situ identification of 25 selected anatomical structures at the end of an anatomy learning unit. The score was the number of structures correctly identified. Analyses of variance showed a significant difference between groups attributable to cognitive style. But when the effect of IQ was removed, there was no significant difference remained that was attributable to the field independence/dependence cognitive style or teaching methods. Further, there was no significant interaction between the cognitive style and teaching methods. The result of this study indicates the importance of controlling IQ effect to judge the true influence of field independence/dependence cognitive style on learning outcomes.

c) Field independence-field dependence and achievement in different subject areas

The field independence-field dependence style has been found to be differentially related to performance in different subject matter areas. For example, in studies with college subjects (Dubois and Cohen 1970;

DeRussy and Futch 1971), relatively field independent subjects were found to perform significantly better in the mathematics, science, engineering and architecture domains than did field dependent subjects. Satterly (1976) investigated the contribution of cognitive styles to the prediction of differences in attainment by school children in English and Mathematics. One-way analysis of variance revealed attainment differences in favour of field independent subjects, in Mathematics and in the knowledge of vocabulary. However, an analysis of coveriance to control for difference in intelligence, showed only the difference in mathematics attainment between the intermediate field independent group and field dependent group to be significant. In another study, Satterly (1979) found that field independence showed a small but significant correlation with achievement in mathematics, geography and English, even after control for general ability. The correlation was greatest for mathematics and lowest for English.

Shavelson (1973) found pupils who scored high on a Hidden Figures Test (i.e. field independent subjects) did better in post-test achievement at the end of five days of learning Newtonian Mechanics than field dependent students. IQ influence was not controlled in this study. Hence, it may be that this difference may be explained in terms of IQ influence since field independence has a low but significant correlation with IQ.

Witkin et al. (1977) have reported a study due to Sieben (1971) in which a significant association between field independence and science performance was found for elementary school children although they acknowledge that in another study (Vernon 1972) no such association was found.

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d) Implications for the present study

The foregoing studies of field independence-field dependence in relation to learning behaviour under different instructional conditions and for different subject matter areas suggest that this cognitive style is of educational significance and that research into its influence on learning and teaching is fully warranted. Thus, the inclusion of field independence-field dependence among the cognitive style selected for the present study is entirely justifiable.

With respect to the present study, which is concerned with the influence of cognitive styles on the discovery/expository modes of learning, it can be hypothesised that there should be a difference in the learning behaviour of field independent persons and field dependent persons in the following respect. In learning situations requiring patterns to be recognised from an array of data and formulated in terms of rules (as in discovery learning), the field independent persons, because of their ability to impose and abstract structure from a seemingly random array of information, should perform better than the field dependent persons. However, in the case of an instructional approach of an extensively expository nature (which would not require any structure to be imposed by the learner), the difference between field independent persons and field dependent persons predicted for the discovery instructional mode, should not exist.

With respect to the second aspect of the present study, that is students' preference for different learning types, the field independent person (again because of his ability to handle seemingly unstructured situations) should find discovery learning relatively easy and more enjoyable than the field dependent person.

2.62 Conceptualisation styles

a) General aspects: characteristics, measurement and IQ correlations

This cognitive style was the product of the work of Kagan, Moss and Sigel (1963). As pointed out earlier, the notion of conceptualisation styles refers to individual consistencies in the use of particular kinds of stimulus properties or relationships as the basis for concept attainment. Three major conceptualisation styles have been suggested. They are as follows:-

i) Relational conceptualisation style - This style is in evidence if an individual groups together different stimuli on the basis of relationships which he assumes to exist between them. For example, given three stimuli, viz. man, watch and ruler, an individual may put together the man and the watch on the ground that the watch is worn by the man. In other words, a relational dependence is invoked between the two stimuli.

ii) Descriptive conceptualisation style - Individuals are said to display a descriptive conceptualisation style if they tend to group stimuli together on the basis of similarities perceived in some physical attributes of the stimuli. Such attributes may be the size, shape, colour, etc., which are shared by the stimuli. With respect to the example mentioned in (i), the selection of watch and ruler on the ground that both show numbers, would be indicative of a descriptive conceptualisation style. The important characteristic is that the attention is focused on the physical attributes of the stimuli and not on the functional link between them as in the relational style.

iii) Inferential conceptualisation style - This conceptualisation style is displayed when stimuli are grouped together on the basis of an inferred characteristic possessed by them without this being inherent in the physical nature of the stimuli. For example, in the above situation, an alternate reason for grouping together watch and ruler might be that they both represent measuring instruments. In this case, no reference is made in the classification to the physical attributes associated with the stimuli.

Kagan, Moss and Sigel (1963) view the relational response mode as the one requiring the least amount of analysis to be made of the stimulus array. To them, relational concepts differ from the descriptive concepts with respect to the part-whole analysis of the stimulus. In the relational concept each stimulus in the group retains its complete identity and is classified as a whole, whereas in choosing a descriptive response the subject has to select from each stimulus a specific sub-element that is similar to a sub-element of another stimulus. Thus, the choice of the mode involves "an active conceptual analysis," while that of the relational mode seems to involve a "passive acceptance of the entire stimulus." The status of the inferential mode is not fully explained by the authors. The inferential classification mode has received only secondary consideration by Kagan and co-workers who couch their argument in terms of the straight forward analytic vs. non-analytic distinction to which descriptive and relational responses lend themselves. In fact, they modified their test by eliminating from it items which typically elicited inferential responses from most children.

Gardner (1963:113) has criticised the undue emphasis given by Kagan and co-workers to the "descriptive" mode. He states:

> "I am troubled by the repeated implication that analytic (descriptive) responses are uniquely "analytic" since it is clearly true that responses called "inferential-categorical" are equally analytic and represent a considerable higher level of abstraction. The analytic response is abstract, but it is not a superior level of abstraction. In actuality, an inferential-categorical response seems to imply everything that an analytic response does, plus something more in the way of abstraction ------."

In the present study, all three modes on conceptualisation are examined for their influence on learning.

Kagan et al. employed two different procedures for the measurement of conceptualisation styles. One involved a sorting task using a variety of human figures and the other task in which pictorial stimuli were presented in triads. The latter was specifically designed for children and required them to select two of the three stimuli presented and to give a reason for putting them together. Other investigations have used the reasons given by individuals for grouping objects together in Object Sorting Tests, as a measure of conceptualisation styles (Wallach and Kogan 1965; Field 1972).

With respect to intelligence, Kagan et al. (1963) report that men assessed as analytic were significantly higher in IQ than other men in the sample. In the case of sixth grade boys, IQ was positively related to the inferential responses in the triads procedure but negatively related to such responses on the human figures sorting task. In other investigations, no significant relationship was found between conceptualisation styles and IQ. In view of this, no firm inferences can be drawn about the association between conceptualisation styles and intelligence.

b) Conceptualisation styles and learning behaviour

Before reviewing studies relating conceptualisation styles to learning outcomes, it must be pointed out that in most studies the conceptualisation styles are dichotomised into analytic and non-analytic thinking style. Leaning towards the descriptive conceptualisation is considered analytic and leaning towards relational conceptualisation non-analytic. The inferential conceptualisation style has received little or no consideration in the studies reported in the literature.

In a serial learning task which consisted of lists of words which are related to each other in functional way (non-analytical), inferential-categorical way, or similarity in sound (analytical), boys who were non-analytic in conceptualisation style recalled more of the functional related words. There was no significant relationship between recall and the analytical/or inferential conceptualisation style (Kagan et al. 1963:84-85).

In a paired associate learning task which consisted of geometric forms on a background and required subjects to learn a nonsense word syllable with each design, children who were highly analytic in the conceptualisation style made fewer errors in matching the words to the figures when the figures alone were presented than did the non-analytic children. But, on the other hand, there was no significant relation between the number of analytic concepts on the human figures sorting task and errors in matching. (Kagan et al. 1963:96).

A study by Beller (1967), cited in Coop and Sigel (1971), appears to indicate that an interaction exists between teaching methods and learners' conceptualisation style. Nursery-school children who were taught to associate words with objects learned much more effectively when the method of language training was congruent with the child's cognitive style. Children who gave descriptive (analytic) responses scored highest on a vocabulary test that involved recognition memory, but those children who gave non-analytic responses on the style test, achieved the highest score on item that involved associate memory. Also, when children were trained by a method congruent with their cognitive style, positive change in performance was observed, whilst children trained with a method dissonant to their cognitive style showed a negative change in performance.

In another study, Coop and Brown (1970) examined the effect of conceptualisation styles and teaching methods, teacher-structured presentation method and an independent problem-solving method on three different aspects of subject matter achievement: factual learning, conceptual generalisation and total content. The study involved 80 college students but, unlike the study with young children, did not reveal any significant difference between students with an analytic conceptualisation style and students with a non-analytic style on any of the dependent measures nor any significant interaction between conceptualisation styles and teaching methods.

c) Conceptualisation styles and achievement in different subject areas

Ogunyemi (1973) investigated the relationship between science achievement and conceptualisation styles. The conceptualisation styles were assessed using the revised 19 items Kagan, Moss and Sigel Conceptual Style Test. The subjects consisted of equal number of high and low science achievers from among grade 7, grade 12 and junior college students. The results indicated that male high science achievers were more inferential and less descriptive in their conceptualisation style than male low science achievers. The difference between the male high and low science achievers on the inferential and descriptive increased with the student's academic level. This, according to the author, supports Gardner's (1963) argument that the inferential style is superior to the descriptive style in terms of a hierarchy of cognitive functions. However, data obtained for the girls did not indicate a consistent distinction in styles between high and low science achievers.

Gray and Knief (1975) investigated the relationship between conceptualisation styles and school achievement, with 275 fifth-grade children. The results indicated that descriptive or analytic style was lowly but significantly related to mathematics achievement. In another study, Roach (1979) with grade 6 children, also found that mathematics achievement had a significant correlation with descriptive style. But, in this study the descriptive style also had a significant positive correlation with intelligence. When intelligence was partialled out the relationship between conceptualisation style preference and mathematics achievement became non-significant.

d) Implications for the present study

The foregoing review of the literature reveals that conceptualisation styles do have some influence on learning behaviour. Therefore, a further investigation of their influence on learning and/or instructional strategies is justified. With respect to the purpose of the present study, the influence of conceptualisation style is likely to manifest itself in connection with discovery learning tasks rather than expository teaching. For this reason, the discussion will focus on the former rather than the latter.

In the direct sense, conceptualisation styles are likely to affect students' behaviour in concept attainment tasks. Concept attainment, as is readily recognised, involves the student in the abstraction of particular stimuli from exemplers with which he is confronted and the synthesis of these stimuli into a pattern or a class embracing all the stimuli. This means that we may associate with concept attainment an analytical component as well as a synthetic component. The analysis refers to the abstraction of stimuli from a set of situations, the synthesis refers to the combination of these stimuli to a common class or category.

Of the three conceptualisation styles, both the descriptive and inferential mode certainly comprise an analytical part; i.e. from a set of stimuli figures presented, some common element has to be abstracted by analysis. This aspect is essentially absent from the relational mode and it may therefore be suggested that this particular conceptualisation style should not have any influence on students' concept attainment.

Of the two modes containing an analytical component it is the inferential conceptualisation style which, in addition to this analysis component, also contains a substantial synthesis component. Through this, the stimuli originally analysed are brought together in a higher order class. This process is essentially one of concept attainment. In so far as the inferential conceptualisation style comprises both analysis and synthesis, it may be hypothesised that it would have the greatest bearing on student concept attainment. The descriptive conceptualisation mode, in so far it does contain an analysis component, may also be expected to have some influence on students' concept attainment skill, but probably to a lesser degree than the inferential mode, because of the absence of the synthesis component.

Linking now the foregoing argument concerning concept attainment and conceptualisation style to the issue of discovery learning, it may be agreed that since most discovery learning involves students in the recognition and formulation of concepts, the inferential conceptualisation style should have a direct bearing on students' success in discovery learning. To a perhaps lesser extent the same might apply to the descriptive conceptualisation mode also, but not to the relational conceptualisation style.

With respect to the second aspect of the present study, i.e. the preference for learning types and cognitive styles the same above argument may be put forward to suggest that high inferential thinkers should express a preference for discovery learning and so should high descriptive thinkers but to a lesser extent, but not the relational thinkers because of their preference for a conceptualisation style which involves more direct type of linkages. They may be expected to prefer a more direct type of learning to discovery learning.

2.63 Conceptual differentiation style

a) General aspects: characteristics, measurement and IQ correlations

When a diverse array of objects is given to individuals for sorting into appropriate groups, wide individual differences are obtained in the number of groups formed. Persons who prefer to form few or many groups are found to be consistent in their preference over a wide range of sorting tasks. This observation, first made by Gardner (1953), led him to postulate a cognitive construct that he initially labelled equivalence range. Subsequently, it was relabelled conceptual differentiation by Gardner and Schoen (1962).

Basically this style seems to involve looking for differences and similarities in a collection of information so that the information given can be differentiated into subgroups each of which contains information that shares some common property. Some individuals, due to their inner characteristic or disposition seem to have the tendency to discern finer points of differences among the stimuli in order to form large number of groups or concepts, whilst others tend to accommodate a wide range of exemplars based on some similarities among the stimuli into a few broad concepts. For example, a group of objects like fork, scissors, spoon, pot, refrigerator, cup, glass, stool may be classified by a low differentiator as items found in the kitchen while a high differentiator would subdivide the items; fork and spoon - to eat food; cup and glass - to drink with; pot and refrigerator - to keep food in, etc.

Gardner and Schoen (1962) used objects, photos and behaviour statements to assess this cognitive dimension. Glixman (1965) employed objects, self-referent statements and items intended to assess attitudes towards nuclear war for the same purpose. In both of these studies, subjects who formed many or few groups in one domain tended to sort in a comparable fashion in another. A correlation of 0.75 between alternative forms of the Object Sorting Test has been reported by Sloanne, Garlow and Jackson (1963). Concerning stability of this style over time, Gardner and Long (1960) found a correlation of 0.75 between the scores of groups of adults derived from two administrations, three years apart, of Gardner's Object Sorting Test.

A complication which arises in Object Sorting Tests, is due to the fact that some subjects are unable to group all items in the sorting task, and accordingly a number of "singles" remain. Gardner and co-workers have scored each object left over as separate groups. Messick and Kogan (1963) have proposed that two separate processes are involved in sorting tasks. The first is a conceptual differentiation and the second is a compartmentalisation. The former represents the number of groups excluding the singles, and the latter reflects the number of singles.

Gardner, Jackson and Messick (1960), exploring the interaction between a variety of cognitive controls and intellectual abilities, found correlations between the object sorting measure and the various ability indices to be uniformly non-significant. Likewise, Sloane, Garlow and Jackson (1963) also failed to establish a significant relationship between vocabulary skill and several forms of object sorting behaviour. But, for a male adult population, Messick and Kogan (1963) found conceptual differentiation to be significantly related to performance on a vocabulary test (r=0.23). This was however, not borne out in a further study by Wallach and Kogan (1965). The conceptual differentiation index of boys in their sample was not related to IQ. Thus, it appears that in general the object sorting indices of conceptual differentiation are quite independent of the traditional intelligence indices.

b) Conceptual differentiation and learning behaviour

Explicit work relating the conceptual differentiation cognitive style to learning/instructional problems is, to the best of the author's knowledge, non-existent. In one study, Field (1972) concluded science and history university students to be relatively high in conceptual differentiation compared with engineering students. He suggests that "there appears to be an analytical tendency among the science and history major students while the engineers' thinking is more orientated to the synthesis of dissimilar events." Field also found high science orientation groups in school samples to lean towards high conceptual differentiation.

Although very little attention has been given to the conceptual differentiation cognitive style, Kogan (1971:261) state that "conceptual differentiation would be a prime candidate for research on the interaction of educational practices and individual differences." Therefore, the inclusion of conceptual differentiation in the present study would serve as an exploration of its influence on learning behaviour.

c) Implications for the present study

The notion of conceptual differentiation style influencing learning or concept attainment is a tricky one because both high and low conceptual differentiation appears to involve an analytical stage. However, in high differentiation the analytical trait would appear to be characterised as adhering close to stimuli and focusing on differences in appearance and/or function of things. In low differentiation, by comparison, the emphasis may be on a search for commonalities among a wide range of stimuli for the purpose of including them in superordinate groups or concepts. Hence, it seems the low differentiation, in addition to its analytic component, also contains a synthetic element. Since, as stated earlier, the key issue in concept attainment is the identification and formulation of patterns, it may be hypothesised that low differentiators should show a relatively better performance in concept attainment task than high differentiators.

Therefore, in relation to learning and instructional strategies, a low level of conceptual differentiation style, should result in an enhanced performance on discovery learning tasks, whilst in expository learning no advantages should accrue from this particular cognitive style.

With respect to preference for learning types, it may be hypothesised that a low level of differentiation may induce positive preference for discovery learning.

2.64 Convergency-divergency

a) General aspects: characteristics, measurement and IQ correlations

The convergent-divergent dimension of cognitive functioning comes from the work of Guildford and his studies concerning "creativity". Although Guildford himself did not consider this dimension to be a style, (Guildford 1967), convergent-divergent thinking is now generally accepted as an individual difference in cognitive processing and is hence often classified as a cognitive style (Messick 1976:22).

The convergent-divergent thinking style refers to an individual's tendency to rely upon thinking that leads to logical conclusions and uniquely correct or conventionally accepted solutions, as contrasted to thinking which leads to a variety and quantity of output. For example, in a task requiring to list as many uses for a common object (e.g. brick), as come to one's mind an individual who generates a large number of uses (conventional as well as less conventional ones), is said to be displaying a divergent thinking style, whereas an individual who lists only a few, conventional uses is said to display a convergent thinking style. It appears that in these tasks the convergent thinker faces some kind of barrier which precludes him from thinking about any use of an object other than the right, the most conventional ones. By contrast, the divergent thinker seems free to use his imagination. Hudson (1966:44) suggests that "what gives the one this skill and the other the aversion is not so much the ability to think as the commitment to (or avoidance of) practical action." Wallach (1970) believes that the difference lies in the breadth of attention deployment. The productive person is better able than his ideationally constricted counterpart to produce a large number of solutions because he is committed to scan and retrieve remote though appropriate information for use in new contexts.

A variety of open-minded tests has been used (Getzel and Jackson 1962; Hudson 1966; Wallach and Kogan 1965) to measure the leanings of individuals on the convergence-divergence dimensions (also known as "creativity"). Some of these tests are verbal in nature while others are non-verbal. What most of these tests have in common is that the score depends not on a single predetermined correct response (as is most often the case with the common intelligence test) but on the number and variety of adaptive responses to a given stimulus task. The most commonly used tests are as follows:

i) Word Association test. The subject is required to give as many definitions as possible to a set of fairly common stimulus words, e.g. bolt, bark, etc.

ii) Uses of Objects or Alternate Uses test. The subject is required to give as many uses as he could for objects that customarily have a stereotyped function attached to them, for example, brick, paper clip, etc.

iii) Instances test. The subject is required to generate possible instances of a class concept, e.g. "Name all the round things you can think of."

iv) Similarities test. The subject is required to generate possible similarities between two objects, e.g. "Tell all the ways in which a cat and mouse are alike."

v) Pattern Meaning test. The subject is presented with a set of pattern drawings and he is required to tell all the things each complete drawing could be.

vi) Circles test. The subject is required to make as many different drawings as possible based on 1 inch circles.

For the present study, only one test was used to measure students' leaning on the convergent-divergent thinking. This was a Uses of Objects test which is described in detail in Chapter 3.

Several scoring procedures have been recommended in the literature some of which are complex and tedious in nature. The usual measures obtained from the divergent thinking tests are (i) a fluency score (ii) a flexibility score and (iii) an unusual uses score. An individual's fluency score in a task is the total number of responses generated. In this, the alternative responses are not generally evaluated for quality. In contrast, an individual's flexibility score in a task is the number of different classes of uses suggested; in this, the quality of responses is taken into account. With respect to the unusual uses score, several different criteria have been used. For example, Hargreaves (1977) refers to "unusual responses" as those given by not more than five subjects, whilst Hudson (1966) refers to them as those given by only 1 to 10 per cent of the individuals in the test population. Hudson (1968) and Vernon (1971) state that the three scores usually intercorrelate highly ($r = 0.7 - 0.8$) and that it is therefore not necessary to distinguish them.

With respect to IQ, Getzels and Jackson (1962) and Hudson (1966) have reported relatively low correlations of the order of 0.2 to 0.3 between IQ and performance on tests requiring the indicated divergent thinking ability. Likewise, the work by Wallach and Kogan (1965) and Wallach and Wing (1969) indicates that the ideational fluency measures within the divergent thinking domain are independent of conventional intelligence indicators. Therefore, these results suggest that the convergency-divergency dimension is a measure of bias, and has no significant overlap with the level of ability.

b) Convergent-divergent thinking and learning behaviour

Valentine (1975) compared the performance on two reasoning tasks with scores on tests of convergent thinking and divergent thinking. The relations between performance on a deductive task (The Four Card problem), an inductive task (The Rule problem), scores on AH5, (General Ability Test) and Uses of Objects test were investigated in 38 first-year undergraduates. The results showed a positive correlation between performance on the deductive task and AH5 as expected, but a negative correlation between performance on the inductive task and Uses of Objects fluency score. Highly divergent thinkers produced significantly more (incorrect) solutions. However, their productivity failed to lead to success on this task as they seem apparently unable to subject their hypothesis to critical analysis. This indicates that convergent thinkers are better equipped to learn from an inductive sequence requiring a unique solution to a problem than divergent thinkers.

c) Convergent-divergent thinking and achievement

Getzels and Jackson (1962:20-28) compared the school achievement of the high creativity group (subjects in the top 20 per cent on the "creativity" measures, but below the top 20 per cent in IQ measure) and the high intelligence group (subject in the top 20 per cent in IQ but below the top 20 percent on the "creativity" measures) on two variables, namely, verbal achievement and numerical achievement. They were measured using standardised achievement tests. They found equal superiority of the high intelligence group and the high creativity group over the total population despite the 23 point difference in IQ between the two groups. Terrance (cited in Getzels and Jackson 1962:25) replicated the above study with eight different samples. In six of the schools he found the same result, despite sizeable differences in IQ, the two groups were equally superior in achievement to the population from which they were drawn.

Feldhusen, Denny and Condon (1965) studied the relationship between anxiety, divergent thinking and achievement. In relation to divergent thinking (as measured by the flexibility scale), they found a pattern of large, positive and significant correlations, all at the 0.01 significance level, with the achievement scores. These correlation coefficients ranged from 0.41 to 0.52. The achievement scores were obtained by the administration of the standard Sequential Test of Educational Progress (STEP). STEP yields normalized achievement scores for mathematics, science, social studies and reading.

Bentley (1966) investigated the relationship between "creative" ability and different kinds of academic achievement represented by Guildford's categories; cognition, memory, divergent thinking and evaluation. Seventy-five graduate students took part in the experiment. Result indicated that "creative" test scores correlate significantly with divergent thinking tasks scores and evaluation abilities ($r = 0.53$ and 0.38, respectively), but no significant correlation was found between "creativity" and cognition and memory.

Hudson (1966), in his study using male sixth-form students, found that far from cutting across the arts/science distinction, the open-ended creativity tests provided one of the best predictors of it. Most arts specialists (English, Literature, History, Modern Language), weak at the IQ tests, were much better at the open-ended one; most scientists were the reverse. This indicates that arts specialists to be on the whole divergers; whilst physical scientists to convergers.

d) Implications for the present study

In general, the above studies indicate that convergent-divergent thinking style has an influence on students achievement. But none of the studies reviewed has examined the influence of this cognitive style on learning behaviour in terms of student achievement under different modes of instruction. It appears that the influence of convergent-divergent thinking style on learning behaviour would depend very much on the nature of the learning problem: as we know that there are certain types of problem that have a unique solution, i.e. where a given set of data can lead to only one possible answer, and, in contrast to this, there is the type of problem that may have a variety of solutions, several of which might be equally adequate. In the "closed" situation the selection of the most appropriate solution is valued, whereas in the "open" situation the generation of a large number of alternate solutions all of which are relevant in some way is valued. However, learning situations in general are "closed" situations where the learner has to examine the given information and arrive at the generalisation that fits all instances. Hence, it may be suggested that in general in learning situations:

i) Convergent thinkers are likely to look for a solution that satisfied all instances, whereas divergent thinkers would look for a range of solutions but, in doing so, may not examine these "solutions" sufficiently critically. Thus the latter's success rate in finding the correct or acceptable solution may be reduced compared with that of convergent thinkers. In the present study this would apply only to the discovery learning situation, as the concepts or rules to be learned are given in the final form in the expository teaching.

ii) The tendency as described in (i) can manifest itself only if the learning situations offered to the student, really allow alternate solutions to be produced. In the present investigation no attempt was made to design deliberately such learning situations. Therefore, the hypothesis stated in (i) may not be satisfactorily examinable in the present study. The inclusion of this part in the study and write up must be considered tentative and exploratory.

With respect to the preference for learning type, it may be hypothesised that convergent thinkers should have a greater preference for discovery learning than divergent thinkers because, in general, discovery learning is a "closed" situation involving the examination of given sets of information and abstraction of patterns or generalisation that fits all information. Divergent thinkers would find such a situation restrictive as generation of alternative solutions to a problem is their mode of cognitive functioning.

2.65 Reflectivity-impulsivity style

a) General aspects: characteristics, measurements and IQ correlations

As stated earlier this style concerns the degree to which the subject analyses the stimuli presented and reflects on the adequacy of a solution hypothesis before reporting. Some individuals select and report solution hypotheses quickly with minimal consideration for their probable correctness, while others take more time to decide on the validity of solutions before reporting. The former type of individual is labelled impulsive and the latter type reflective. For example, when presented with a standard object and six variants one of which is identical to the standard and asked to select it some individuals respond fast and often make more errors while others take a long time to decide.

The reflectivity-impulsivity disposition has been assessed by a variety of instruments, such as the Hidden Figures test, the Design Recall test, the Haptic Visual Matching test, and the Matching Familiar Figures test (Kagan et al. 1964, Kagan 1966). Of these, the Matching Familiar Figures procedure is now consistently employed by researches as the basic index of reflectivity-impulsivity. Each item in the instrument contains a standard stimulus and six variants, one of which is identical to the standard. Response time to the first hypothesis and the number of errors constitute the major variables. The number of items in the different forms of the test varied from 5 to 20. The correlation between the two variables is negative and tend to range from 0.40 to above 0.60 (Kagan et al. 1964, Kagan 1966).

The best evidence on the test-retest reliability of MFF tests (over a period of three weeks) is presented by Adams (1972) in a study involving 50 first grade children. For response time the correlation was 0.58 ($p<.01$), while for the error scores reported only for girls it was 0.39 ($p<.01$). Cairns (1977) reports internal consistencies for a 12 items MFF test using the split-half method, as follows: for 9-year olds, the response time correlation was 0.94 ($p<.001$) and that for errors 0.46 ($p<.01$), whilst for 12-year olds the corresponding correlations were 0.95 ($p<.001$) and 0.52 ($p<.001$).

The degree of reflection as measured by response time shows a remarkable generality across a variety of tasks and marked intra-individual stability over both short and relatively long periods (Kagan et al. 1964; Messer 1970; Yando and Kagan 1968). However, Kagan et al. (1964) brings to attention that the degree of consistency for response time is limited to problem situations that give rise to many response alternatives simultaneously and where the correct alternative is not immediately obvious.

With respect to the influence of IQ, Kagan et al. (1964) found no relationship between response time and IQ. The r values ranged from -0.01 to 0.15, all non-significant, but there were low negative correlations between IQ and error scores. The r value ranged from -0.21 to -0.47.

b) <u>Reflectivity-impulsivity and learning behaviour</u>

In learning problem situation with alternative routes to solution, reflection upon the probable validity of varied solution sequences is critical for the ease with which success is achieved. Individuals who do not reflect upon the differential validity of several solution possibilities are apt to implement mentally the first idea that occurs to them. This strategy is more likely to end up in failure than one that is characterised by reflection. Research evidences are generally in support of this view.

Kagan (1965) studied the effects of impulsiveness on reading ability with first grade children. He found that children who displayed long decision time and low error scores on the MFF test were the most accurate in the recognition of words. This relationship between reflective disposition and reading error remained significant even after the influence of verbal skill had been partialled out.

In another study, Kagan (1966) examined the effect of reflectivity-impulsivity on memory task. The results showed that reflective subjects recalled more words than the impulsives. Also, the analysis of variance on intrusion errors revealed a significant F-ratio ($F=7.38$, $p<.01$) for the reflectivity-impulsivity dimension, with the impulsive subjects producing more intrusion errors than their reflective counterparts.

Kagan and others (1966) in another study explored the relationship between reflectivity-impulsivity disposition and inductive reasoning in a sample of first grade children. They found that, on the whole, impulsive children responded more quickly and made more errors on the inductive reasoning tasks. The relationship remained statistically significant even with verbal ability control.

Messer (1970) found children who failed a grade were significantly more impulsive than their peers although they were highly comparable in verbal intelligence.

c) Implications for the present study

The results of the above studies give a general picture in which the learning behaviour of a reflective individual who is more likely to examine all of the alternatives is more conductive for success in learning tasks than the learning behaviour of an impulsive individual who is more likely to act upon the first idea that comes to mind. Hence, with respect to the purpose of the present study it can be hypothesised that the individual difference is reflective-impulsive behaviour should have an influence on learning. In learning situations requiring careful examination of stimuli presented and abstraction of pattern or rules that fit all given information as in discovery learning, the reflective individuals should be better equipped than impulsive individuals to handle such situations because impulsive individuals under such circumstances would settle for the first obvious relationships they find in the data and these impulsive hypotheses are apt to be incorrect or inadequate. On the other hand, in the expository learning situation where the pattern or rule to be learned are given in the final form to the leaner the impulsive individuals are not faced with the problem of examination of data and generation of rules, as such we should expect any difference that exists between reflective and impulsive individuals in discovery learning situation to be narrowed or even eliminated by the expository teaching approach.

Where preference for learning type is concerned, we should expect the impulsive individual to have less favourable attitude or feeling towards discovery learning relative to reflective individuals because impulsive individuals are likely to meet repeated failure in discovery learning task and hence would find discovery learning difficult, unrewarding and threatening.

2.7 DISCOVERY-EXPOSITORY LEARNING

The issue of learning by discovery and expository has been investigated with great frequency over the past four decades, or so. The literature in the field of instructional strategies research cites hundreds of studies which have sought to compare forms of learning by discovery with expository, reception or didactic learning. As the main concern of the present study is not the comparison of learning by discovery and expository approach the review will be restricted to the nature of the two modes of learning, and the discussion of the general research findings.

a) Nature and classification of instructional modes

First of all there is a considerable ambiguity in literature over the use of the term discovery, as it has been used to describe many varied forms of teaching-learning situations. There is no widely accepted definition of this term. Ausubel (1963:16) has defined discovery learning as follows "----the principal content of what is to be learned is not given -----". Bruner (1961:22) defines discovery learning as "----a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so assembled to additional new sights." Further, Ausubel believes that learning can be dichotomised as discovery and expository and defines expository learning as that in which "the entire content of what is to be learned is presented to the learner in final form."

To add to the confusion concerning the discovery-expository teaching dichotomy, teaching has also been categorised as inductive and deductive. Inductive teaching defined as being based on the presentation to the learner of a sufficient number of specific examples to enable him to arrive at a definite rule, principle or fact. Deductive teaching being a method "that proceeds from rules or generalisation to the application of the generalisation." Many experimenters have equated discovery learning with inductive learning. But, Ausubel maintains that four distinct forms of teaching can be distinguished by the combination of the discovery-expository dichotomy and the inductive-deductive dichotomy. The table below represents Ausubel's classification scheme.

	Discovery	Expository
Inductive	A	B
Deductive	C	D

Ausubel's distinction of discovery versus expository and inductive versus deductive was an attempt to clarify the problem of classification teaching approaches, but his scheme was still inadequate to fit all the differences in design of teaching. Schwab (1962) distinguished between three components of the learning situation: (i) problems (ii) ways and means for discovering relationships and (iii) answers. Using these distinctions, Shulman and Tamir (1973) formulated a scheme to fit learning situations with different levels of guidance. Their scheme is presented in the table below.

Level of openness	Problem	Ways and Means	Answer
0	given	given	given
1	given	given	not given
2	given	not given	not given
3	not given	not given	not given

Level 0 in this scheme represents expository teaching whilst level 1, 2 and 3 represents discovery teaching approaches of varying levels of guidance or openness. This picture of teaching methods resulted in viewing discovery-expository teaching not as dichotomous but as a spectrum ranging from complete openness with no guidance to a closed situation where everything is given to the learner.

In 1969, Hermann has suggested a further way in which teaching approaches may be classified based on the operations used in teaching the material. The scheme suggested by him is given below in a tabular form.

type	instructional sequence variations		
1	Rule given -	examples given	- Answer given
2	Rule given -	examples given	- Answer not given
3	Examples given -	answer given	- Rule not given
4	Examples given -	answer not given	- Rule not given
5	Examples given -	answer given	- Rule given
6	Examples given -	answer not given	- Rule given

In view of the numerous ways in which instructional sequence may be organised it is now generally agreed that the teaching strategies investigated should be described in detail in order to give the reader a clear picture of what it meant by discovery and expository in the respective investigations. With respect to the present study, detailed description of the instructional sequences of the learning tasks are given in Chapter 3. Therefore, at this point it will suffice to say the discovery sequence in the present study involved the presentation of sets of exemplars which the learner had to analyse in order to abstract generalisations or rules. It corresponded to the type 4 situation in terms of Hermann's suggestion. The expository mode consisted of a sequence in which worked examples were given together with an explicit statement of the rule or generalisation. It corresponded to the type 5 situation in terms of Hermann's suggestion.

In studies comparing the effectiveness of instructional approaches the general research strategy has been to assign subjects randomly to two or more instructional conditions and to compare the average performance on some criterion. The criteria normally used are chosen from performance on immediate retention tasks, on long-term retention tasks and on transfer-of-learning tasks.

b) General hypotheses and research findings

The advocates of discovery learning like Bruner and others have claimed a number of advantages for discovery learning over expository learning. For example, learning by discovery is thought to (i) help increase a person's ability to organise information which in turn aids memory and makes the organised information more readily available for later application or problem solving, (ii) develop discovery skills which help in the transfer of learning from one context to the next and (iii) foster self-motivation in learning and problem solving. But Ausubel, an advocate of the meaningful verbal learning, has contrasting view points concerning the usefulness or otherwise of discovery learning. For example, he claims that meaningful verbal learning can aid memory as well as discovery learning and that discovery learning is more associated with extrinsic motivation than is reception learning.

The evidence from empirical studies on these issues are not all that consistent. Hermann (1969) made a critical review of some twenty five studies carried out between 1956 and 1968. With respect to immediate retention criterion he found two studies (Belcasto 1966; Kittell 1957) in favour of expository learning and one study (Rowlett 1960) in favour of discovery learning. With respect to long term retention, two studies (Craig 1956; Kittell 1957) favoured expository learning and one study (Rowlett 1960) favoured discovery learning. When the transfer of learning was the criterion he found ten studies (e.g. Ray 1961; Rowlett 1960; Gutherie 1967) in favour of discovery learning and only one study (Kittell 1957) in favour of expository learning. However, a large number of studies he examined showed non-significant differences (e.g. Rowlett 1966; Forgus 1957; Kersh 1962).

The inconsistency of the results has led researchers to think anew about the question of discovery-expository instruction. They now reckon that the research approach used (i.e. direct comparison) may be at fault in that it ignores the implication of individual differences among students and thus obscure the differential effect that any one method might have on students with different individual characteristics. Messick (1970) has called such "putting" of one instructional method against another, while ignoring the suitability of either method to the individual characteristics, "horse-race" evaluation. He goes on to suggest that it is time to put aside the problematic question, "Is teaching through discovery better than expository teaching?" and move on to discover which set of students benefit from the different instructional procedures.

With the isolation of individual differences in cognitive styles it is now hypothesised that these stylistic individual differences might be major determinants of the kind of instructional approaches that work best with different individuals. Some studies along this line have already been undertaken especially with respect to the field independence-field dependence cognitive style. They have already been reviewed in Section 2.61 (b) of this chapter. The present study is another exploratory attempt to investigate the influence of a few selected cognitive styles on students learning behaviour under different conditions of learning.

CHAPTER 3 RESEARCH DESIGN, METHODOLOGY AND ADMINSTRATION

3.0 INTRODUCTION

As has been stated in Chapter 1, the study reported here was concerned with an exploration of (i) the effect of five different cognitive styles on learning from two different instructional procedures, (the discovery mode and the expository mode), and (ii) the relationship between students' cognitive styles and their preference for the two different instructional modes. The cognitive styles chosen for this study were the following:

i) Field independence-field dependence
ii) Conceptualisation styles
iii) Conceptual differentiation
iv) Convergency-divergency
v) Reflectivity-impulsivity

The possible effects of these cognitive styles on learning have already been explored and discussed in Chapter 2, which dealt with the review of literature.

3.1 RESEARCH STRATEGY

The present investigation was carried out in two phases. In Phase I of the study, an examination was made of the effects of the first four cognitive styles listed above, on learning from a set of five short learning exercises which had previously been used in several published researches into the comparative effectiveness of discovery learning and expository teaching. The exercises involved the following tasks:-

a) Unscrambling scrambled words
b) Uncoding coded words
c) Completing a letter series

d) Completing a number series

e) Finding the formula for calculating the sum of an odd-number series

Each exercise was developed in two formats, one corresponding to the discovery mode of instruction, the other corresponding to the expository teaching mode. These exercises are described in detail in Section 3.41 in this chapter, as are the tasks developed to measure students' learning from the exercises. In addition to the learning exercises and tests relating to them, the following tests were also administered in the Phase I study:-

i) cognitive styles tests relating to the cognitive styles mentioned above

ii) a "preference for learning types inventory" designed to assess students' preference for the two instructional modes employed in the study.

Phase II of the study involved a further examination of the effects of cognitive styles on learning, but this time with respect to a set of Chemistry learning tasks. For this purpose, four units of Chemistry learning material dealing with aspects of Periodic Table, stoichiometry and formulae of compounds, were developed. Details of these learning units and achievement tasks relating to them are given elsewhere in this chapter. The same set of cognitive styles was examined as in the Phase I study, but a further style was also included: that of reflectivity-impulsivity. In addition, the AH4 group test of general intelligence was also administered. Figures 3.1 and 3.2 summarise the learning tasks and tests used in the two phases of the study.

In the following sections of this chapter, a description is given of the cognitive styles tests and ancillary tests, of the learning tasks,

PHASE I STUDY

Cognitive styles measures

field independence/dependence
conceptualisation styles
conceptual differentiation
convergency-divergency

Learning tasks

scrambled words
coded words
letter and number series
sum of odd-number series

Ancillary test

Preference for learning types

Figure 3.1 Learning tasks and tests used in Phase I of the study

PHASE II STUDY

Cognitive styles measures

field independence/dependence
conceptualisation styles
conceptual differentiation
reflectivity-impulsivity
convergency-divergency

Learning tasks

4 units of Chemistry
learning material

Ancillary test

AH4, general intelligence
test

Figure 3.2 Learning tasks and tests used in Phase II of the study used in the two phases of the study, of the student samples employed and the administrative procedure adopted. This is done in the following manner. In Section 3.2 for each cognitive style selected for this study a brief discussion of the approaches for its measurement is given. This is followed by a description of the test (and, where applicable, its development) employed and the scoring procedures adopted. In Section 3.3 the ancillary tests are described. This is followed by the description, in Section 3.4 of the learning exercises and achievement tasks used in the Phase I study and developed for the Phase II study. Finally, in Sections 3.5 and 3.6, the student samples participating in the two phases of the study are described and the administrative procedures outlined.

3.2 COGNITIVE STYLES MEASURES

As has already been stated, five cognitive styles were selected for investigation in this study. They were:-

i) Field dependence-field independence

ii) Conceptualisation styles

iii) Conceptual differentiation

iv) Convergency-divergency

v) Reflectivity-impulsivity

For each of these cognitive styles, approaches to its measurement will now be discussed and a description given of the test or tests used for its measurement in this study.

3.21 Field independence-field dependence measures

The original measures for the field independence/dependence dimension, used by Witkin et al., were the Rod and Frame Test (RFT) and the Body Adjustment Test (BAT). Both tests require an administration on a one-to-one basis and have thus little value for work with large populations. In

1971, Witkin et al. developed a group test which made the study of field independence/dependence of large population a relatively simple matter. The test in question was an "embedded figures" test which requires subjects to identify relatively simple geometrical figures (acting as stimuli) in an array of geometrical information. Field independent people have a high ability to distinguish in these situations between "signal" and "noise" whereas field dependent persons lack this ability. The validity of embedded figures tests as a means of determining field independence/dependence rests entirely on the moderately high correlation between the results from such tests and those derived from the application of the RFT and BAT. In recent years, other investigators have developed alternative versions of embedded or hidden figures tests, for example, Jackson et al. 1964; Gardner et al. 1960; Satterley and Telfer 1979 and Kempa and Cox 1976.

In the present study, two such tests were employed: the Concealed Shapes Test developed by Satterley and Telfer and the Hidden Figures Test by Kempa and Cox. Both tests were selected because they were easily available, and economical to use. Also the time requirement for their administration made them ideally suited to the present study.

a) <u>The Concealed Shapes Test</u>

The Concealed Shapes Test consists of 24 rows of shapes. Each row presents a simple shape, followed by four complex figures. The latter figures represent the test items. Subjects are required to judge whether or not the simple figure is embedded or hidden in the complex figures following it. The responses are recorded in the test booklet itself. The test as used contained 24 x 4 = 96 individual items to be judged. In 51 of these, a simple figure was embedded in the complex figures, whilst it was absent in the remaining 45 complex figures. A copy of the Concealed Shapes Test is given in Appendix A.1. The time allowance for the completion of the test was 12 minutes.

b) The Hidden Figures Test

The Hidden Figures Test is similar in structure to the Concealed Shapes Test but contains only 48 items, again presented in rows of four complex figures and one simple figure. Its main difference from the Concealed Shapes Test is that it comprises only straight-line drawings, whereas the Concealed Shapes Test figures use straight-line and curvilinear drawings. The time allowance for the completion of the HFT is 12 minutes, as for the CST, but responses are recorded on a separate answer sheet. The advantage of this is that the test booklets are re-useable. A copy of the Hidden Figures Test is given as Appendix A.2. It should be noted that the Hidden Figures Test was used for Phase II of the study only, whereas the Concealed Shapes Test was used in both phases.

The customary scoring procedure for embedded figures is to count as correct all items for which the presence or absence of the appropriate stimulus figure is correctly identified. The tacit assumption underlying this procedure is that the task of identifying the presence of stimulus figure is identical, in psychological sense, to the task of identifying the absence of a stimulus figure. Kempa has challenged this assumption (on the basis of his work with Ward on students' observational behaviour in chemistry (Kempa and Ward 1975)) and has proposed a scoring procedure whereby separate scores are obtained for "present" items and "absent" items. This procedure was adopted throughout the present study, for both embedded figures tests used. The extent to which Kempa's proposal is justified, is examined in Chapter 4 Section 4.81.

3.22 Conceptualisation styles measures

Kagan et al. (1963) have used, for the purpose of measuring conceptualisation styles, a "figures sorting" exercise in which subjects are presented with triads of pictures and requested to (a) select from these triads a pair of figures/pictures and (b) indicate the reasons for selecting the pair. These reasons are then analysed in terms of the conceptualisation styles inherent in them. The reasons may either have to be "constructed" by the respondent, or are presented as part of the test and have to be selected from by the student (Cohen 1972). Other authors, for example, Wallach and Kogan (1965) have used the Object Sorting Test for the purpose of measuring conceptualisation styles. This has already been discussed in Chapter 2.

In the present study, both approaches to the measurement of conceptualisation styles were explored. On the one hand, a specially designed conceptual preference test was employed; on the other, the reasons for grouping items in the Object Sorting Test were analysed and the results used as a measure of conceptualisation styles. Both tests are described below.

a) Conceptual Preference Test

The Conceptual Preference Test used for the study consists of 24 triads of line-drawing pictures of common objects. It had been designed by Kempa, following the pattern described by Sigel (1963). Each picture also carries the name of the object depicted in it, so as to avoid any ambiguity. For each triad, three statements are given expressing, respectively, a relational linkage, a descriptive linkage, and an inferential (categorical) linkage between two of the objects. The order of these statements is entirely random for the test as a whole. A copy of the test is given in Appendix A.3.

In completing the test, students were asked to select from the three responses given for each picture triad the one they most preferred and the one they least preferred. Responses were recorded on a separate answer sheet. No time limit was set for the completion of this test. Most of the subjects completed the test within twenty minutes.

The procedure adopted for the scoring of this test was as follows. Three points were assigned to the most preferred statement; one point to the least preferred statement and two points to the remaining one. On this basis, three scores were derived for each student expressing, respectively, his (i) preference for inferential concepts, (ii) preference for descriptive concepts, (iii) preference for relational concepts, with the scores ranging from 24 to 72. The scores obtained in this way are ipsative in nature, i.e. have the characteristic of adding up to a fixed total:

$$S_{\text{inferential}} + S_{\text{descriptive}} + S_{\text{relational}} = \text{Constant}$$

Whilst ipsative scores have the advantage of providing high discrimination between the responses modes and thus enhance the distinction between students in relation to their preference for different conceptualisation styles, their interpretation is somewhat problematic because of the interdependence of the scores. This makes the usual statistical procedures of data analysis inappropriate and inapplicable, ruling out, for example, correlational work. There is no easy solution to this problem. Researchers using the ipsative conceptual preferences test have either dichotomised the student sample in terms of two of the scales, e.g. descriptive vs. relational, ignoring thereby the third score (Kagan et al. 1963; Scott 1973) or they have treated each scales as an independent variable, without reference to the remaining two scales. In the latter case, normative statistics have generally been used for the data analysis (Wallach and Kogan 1965; Ogunyemi 1973). For the purpose of the present study, the latter procedure has been adopted, treating the three scales as independent measures of conceptualisation styles.

b) Objects Sorting Test

This test was adopted from the work of Clayton and Jackson (1961) and consisted of 50 line-drawings of common every-day objects set out in rows of fives on a single sheet of paper. Each picture also carried the name of the object, as in the Conceptualisation Preference Test, to avoid any ambiguity. Subjects were required (i) to collect and list on a separate answer sheet all objects that seemed to belong together in some way, and (ii) indicate a reason for putting them together. No time limit was set for the completion of the test. Most of the subjects completed the task in 30 minutes. A copy of the test is given in Appendix A.4.

To get a measure of a students' leaning towards the three conceptualisation styles, the reasons given for putting objects together were classified as 'descriptive', 'inferential' or 'relational'. This was done with the help of guidelines adopted from the work of Wallach and Kogan (1965). The guidelines are given below.

Descriptive Conceptualisation is the grouping together of objects on the basis of similarity in objective, physical attributes among a group of stimuli. The following types of reason were classified as being descriptive in character:

i) reasons based on directly observable physical attributes (e.g. coin, tyre - both are circular);

ii) reasons based on knowledge of some integral physical attributes (e.g. lamp, flashlight, candle - they all give light);

iii) reasons referring to the origin of material of which the objects are made (e.g. purse, wallet, shoe - made of leather);

iv) reasons based on integral function capable of the objects (e.g. cup, glass - both can hold drinks);

<u>Inferential Conceptualisation</u> involves the grouping together of objects because of some characteristics shared by all; but what they share is not inherent in the physical nature of the stimuli grouped. The following types of reason were judged to be inferential in character:

i) reasons based on usage of a group of objects, whereby the usage does not depend on any specific physical attribute common to all objects (e.g. stool, rug, carpet - for sitting on);

ii) reasons based on location of the group of items (e.g. tree, flowers, rake - found in the garden);

iii) reasons based on membership of a class (e.g. pistol, arrow - weapons);

iv) reasons based on inferred properties (e.g. candle, cigarette - one can light them with a match).

<u>Relational Conceptualisation</u> is the grouping together of objects because of the relationship between or among the stimuli grouped. The following types of reason were classified as being relational in character:

i) reasons based on functional relation (e.g. key, door - key used to open the door);

ii) reasons based on complementary relations (e.g. purse, coin - purse to put coin in);

iii) reasons based on a theme (e.g. shoe, hat, jacket, lipstick - things that can be used for 'dressing up');

iv) reasons indicating multiple group labels where the objects are not simultaneous members of both labels (e.g. shoe, hat, jacket, hanger - clothes worn or on what they can hang).

In spite of these guidelines, difficulties were encountered in the allocation of some of the reasons given. In such cases a second opinion was sought.

The raw scores obtained by the above procedure are not suitable for comparison, because they do not provide information about a person's preference for leaning towards a particular conceptualisation style. This is due to the difference in the total number of groups formulated by the different subjects. To overcome this problem, the percentage scores which reflect the relative standing of an individual on the conceptualisation styles scales were calculated, i.e.,

$$\text{percentage score} = \frac{\text{Number of groups of one type} \times 100}{\text{Number of all groups.}}$$

3.23 Conceptual differentiation measure

The difference between individuals in terms of their conceptual differentiation, the cognitive style dimension proposed by Gardner and Schoen (1962), was measured by the Object Sorting Test. The test has already been described in the above section dealing with conceptualisation styles. The number of groups formed by an individual that contained two or more items, constituted the individual's conceptual differentiation score. The definition or reason for each group formed, served as a basis for determining the number of groups conceptualised. Objects left unclassified were not taken into consideration in the scoring of the number of groups. This is in line with the procedure suggested by Wallach and Kogan (1965) mentioned in Chapter 2 Section 2.63.

3.24 Convergency-divergency measure

The Uses of Objects Test, is one of the open-ended tests widely used to measure this trait, and was selected for use in the present study. Getzel and Jackson (1962) used five objects in their test, whilst Hudson (1966,1968) has used three to five objects in his tests. The test for the present study employed six items (newspaper, brick, paper clip, tin can, cork, blanket) all of which were selected from the above mentioned tests.

The test required subjects to think and list as many different uses as they could for each item in the test. No examples were given to aid the subjects in their line of thinking and no time limit was set for the test. This is as has been suggested by Wallach and Kogan (1965). Most subjects completed that test within 15 minutes. A copy of the test is attached in Appendix A.5.

The test was scored for ideational fluency and flexibility. The fluency score of an individual was equal to the total number of uses suggested for the six items in the test, irrespective of the quality of the responses. The flexibility score was equal to the sum of the number of different classes of use given for each of the items. To exemplify this, a subject generating the following uses for the item brick:- to build house, to build church, to build garage, to build wall, etc., would have generated a large number of uses, but without departing from the single basic concept of the brick being a construction material. Hence, he would obtain a high score for fluency but a low one for flexibility. By comparison, a subject suggesting uses for a brick such as to build houses, to stop a door, as paper weight, as a hammer, to break a window, etc., would have used more than one property of the brick to generate the uses. Hence, he would obtain a high score for both fluency and flexibility. The flexibility score was obtained by grouping the responses of an individual into different classes with the help of a scheme specially developed for this purpose. The scheme consisted of between 10 and 12 categories of uses per items based on such concepts as the conventional uses of the object, shape of the object, properties of the material, etc. The scheme is also attached in Appendix A.5. Each of the uses suggested by a subject was fitted into one of these categories. The flexibility score was arrived at by summing the different classes of uses suggested for each of the six items.

3.25 Reflectivity-impulsivity measure

The Cairns' version of the Matching Familiar Test (Cairns and Cammock 1978) was used in the present study. The test comprised of two practice items and twenty test items. A typical item in the test consisted of a familiar object called the standard and six variants of it. A few sample items are given in Appendix A.6. (A copy of the full test can be obtained from Dr. E. Cairns, Dept. of Psychology, The New University of Ulster, Coleraine, Northern Ireland).

The test was administered individually to each subject. The subject was shown a picture of the standard object on a card and then the six variants of the objects on another card. The cards were placed one above the other in front of the subject. Then the subject was instructed to select the one variant that is exactly like the standard. The response time of the subject's first hypothesis was recorded. If the subject selected the wrong variant, he was asked to try again until he got the right one. The number of errors thus made was also recorded. Hence, two measures were obtained for each subject: (i) the mean response time to the subject's first hypothesis on each of the 20 items, and (ii) the total number of errors over all 20 items.

3.3 ANCILLARY TESTS

As pointed out in Chapter 1, two further tests were administered in the context of present study, in addition to the cognitive styles measures already identified and the achievement measures which may be considered an integral part of the learning experiences themselves. The first of these was an IQ test, for reasons outlined below; and the second a "preference for learning types" inventory developed specially for this study.

3.31 IQ - Test

The reason for including an IQ test in the battery of tests used in the present study, follows from the findings of several researchers that certain cognitive styles measures correlate lowly, but significantly with IQ. This, as was pointed out in Chapter 2, is particularly well established in relation to the field independence/field dependence style, especially when measured by means of embedded figures tests. To be able to judge the effect of a cognitive style which is associated with IQ, upon students' learning behaviour, it is expedient to "partial out" any IQ effects. This requires a suitable IQ instrument to be administered.

In the present study, the AH4 group test of general intelligence (Heim 1975) was judged to be a suitable instrument. It is a test which covers three aspects of IQ: verbal reasoning, numerical reasoning and spatial reasoning. Items testing the first two forms of reasoning are combined into one sub-test (Part 1, AH4), while spatial reasoning items form a separate sub-test (Part 2, AH4). In normal IQ evaluations, scores on Part 1 and Part 2 are treated additively and the manual for the test makes no mention of any significance to be attached to the sub-tests separately. However, for the purpose of the present study sub-test scores were obtained as separate scores, in order to allow the relationship between performance on cognitive styles measures and IQ biases to be examined. Since the AH4 test is widely known and well established for IQ measurements, no copy of the test is included in the Appendix. It should be mentioned that the IQ test was used only in conjunction with the "Phase II study," i.e. that involving the chemistry learning tasks.

3.32 Preference for Learning types inventory

In addition to the interest in the relationship between cognitive styles traits and learning behaviour, especially in context with discovery and expository learning tasks, a further aspect examined in the study was the relationship between students cognitive styles and their preference for different types of learning. Since the instructional strategies under consideration in this study were discovery and expository instruction, it was decided to base this enquiry on two constructs: the ease or difficulty of the two approaches and the enjoyment of/dislike for the two approaches in terms of the extent to which they were thought to be engaging and interesting or dull and boring.

Each construct was measured by a set of six rating items, developed as "semantic differential" items (Osgood, Suci, Tannenbaum 1967). A copy of the inventory is given in Appendix A.7. The inventory was examined for scale reliabilities, in the normal manner, and the results of this are reported in Chapter 4.

It should be noted that the preference inventory was used only in connection with the Phase I study. Before completing the inventory, subjects had had experience of both discovery based and expository based learning units and were thus able to make comparative judgements about both approaches.

3.4 DESIGN OF LEARNING TASKS/UNITS

As was stated in Chapter 1 for the purpose of the present investigation a deliberate decision was made that learning and instruction should be considered here in terms of discovery and expository approach. But there exists a considerable ambiguity over the use of the terms discovery and expository, as they have been used to describe many varied forms of teaching/learning situations. This has been discussed in Chapter 2 Section 2.7. In the context of the present study discovery learning/ instruction consisted of learning situations in which the learner was provided with a set of exemplars implying a particular rule. The learner was required to "decode" the exemplars, i.e. identify or deduce the rule implicit in them. In short, as pointed out in Chapter 2 Section 2.7 the present discovery approach may be summarised as: exemplars given - answers not given - rules not given. By contrast, in the expository instructional approach a particular rule was explicitly pointed out to the learner and amplified by examples illustrating the rule. In brief, the expository approach may be summaried as: examples given - answers given - rule given.

Also, it was decided that the learning materials should be presented in a "programmed learning" format, in self-contained booklets. The reason for this was that in this particular way it was possible to eliminate teacher-variability as a possible influence on how well or badly students with different cognitive styles orientation might learn. One particularly important reason why teacher influence should be eliminated from studies of this type is the finding by Distenfano (1969); Moore (1973), as cited in Witkin (1977); Hudson (1968); and Yando and Kagan (1968) that the teacher's cognitive styles have a significant influence on the teaching modes and teaching approaches which they prefer as well as on the interpersonal relationship with pupils in learning situation.

As stated in the introduction to this chapter, the investigation was carried out in two phases. In the Phase I study, five short (non-chemical) learning tasks were used. Details of these tasks are given below. For the Phase II study, four units of chemistry learning materials were specially developed. They are described in a subsequent section.

3.41 <u>The Phase I study learning tasks</u>

The five short learning tasks used in the Phase I study were labelled thus:

i) Scrambled Words Task,

ii) Coded Words Task,

iii) Letter Series Task,

iv) Number Series Task,

v) Sum of Odd-Numbers Task.

Each of these learning exercises, including any post-learning tasks and achievement tests relating to them, are described in the following sub-sections.

i) <u>Scrambled Words Task</u>

The scrambled-words task which was adopted from the work of Guthrie (1967), involved the unscrambling of scrambled words. The words had been scrambled by transpositioning the letters in the words. All the words in this learning task were 4,5,6 or 7 letter common words. Three different patterns of scrambling were used in the present study:-

a) The position of the first and last letter in the words was interchanged. This pattern of scrambling applied to words with any number of letters (e.g. SMILE - EMILS).

b) The second pattern of scrambling applied only to words with an even number of letters. The letters in the words were divided into two halves. The position of the first half of letters was interchanged with the second half of letters (e.g. NUMBER - BERNUM).

c) The third pattern of scrambling applied only to words with an odd number of letters. The first letter of the word was placed in the middle of the word (e.g. STYLE - TYSLE).

For each of these subtasks the students were provided in the discovery version with ten exemplars to unscramble and abstract the implicit pattern inherent in the subtasks, and four scrambled words sentences to practice the rules discovered thereafter. For each subtask in the expository version, the students were given five worked examples for each subunit, together with a statement of the rule for unscrambling the words. For practice, they had a further set of five words and the four sentences of scrambled words as in the discovery version.

The learning outcome was assessed by a separate post-test. The test required students to accomplish three types of tasks:

a) the statement of the rules learned in the unit.

b) the direct application of rules to a further set of problems (two for each rule).

c) the application of the rules in an inverse way, where the subjects had to transform each rule mentally to get a reverse rule and apply it to a set of problems (two for each rule). The subjects had not experienced this type of situation in the learning phase.

A copy of this learning unit and the post-test is attached in Appendix B.1.

ii) Coded Words Task

This task was similar to the scrambled words task described above and has also been adopted from the work of Guthrie (1967). It involved the decoding of words which had been coded by the substitution of one or more letters in a word by another letter or letters. As in the first task, the words used were common 4,5,6 or 7 letter words. Four patterns of substitution were employed in this task.

a) The last letter of the word was substituted by the letter after it in the alphabet (e.g. LOAF - LOAG).

b) The first letter of the word was substituted by the letter preceding it in the alphabet (e.g. TABLE - SABLE).

c) The first and last letter of the word were substituted by the letters before and after them in the alphabet, respectively (e.g. SUBJECT - RUBJECU).

d) Each letter in the word was substituted by the letter preceding it in the alphabet (e.g. BRIEF - AQHDE).

The design of the learning phase and the post-test for this task was very similar to that for the scrambles words task. A copy of this learning unit and the post-test is attached in Appendix B.2.

iii) and iv) Letter Series and Number Series Tasks

Both these tasks were adopted from the work of Simon and Kotovsky (1963) and were concerned with the identification of patterns in letter series and number series. They were both presented in the same learning booklet. Four different letter sequences and four different number sequences were used in the learning tasks. The letter sequences used in the study were as follows:-

a) The first type of letter series consisted of three-letter sets with the first two letters remaining unchanged and the third letter changing from a to b or b to a (e.g. mnamnbmnamn ; atbatastbat).

b) The second type of letter series consisted of three-letter sets with the first and third letter remaining unchanged and the second letter changing to the next letter in the alphabet in the successive sets (e.g. krtkstktt).

c) The third type of series consisted of two-letter sets with both letters in successive sets each changing to the next letter in the alphabet (e.g. mbncod).

d) The fourth type of letter series consisted of three-letter sets with all the letters in each successive sets changing to the letters coming before them in the alphabet (e.g. tmesldrke).

The number sequences used in the study were of the following types:-

a) The first type of number series consisted of three-figure sets with the first two figures remaining unchanged and the third figure increasing in value by one (e.g. 524525526).

b) The second type of number series consisted of two-figure sets with the successive sets differing by 11 units (e.g. 786756 or 324354).

c) The third type of number series consisted of three-figure sets with the first and second figure increasing by one unit and the third figure increasing by two units in the successive sets of figures (e.g. 421533645).

d) The fourth type of number series consisted of four-figure sets with the successive sets having the figures in reverse order (e.g. 123443211234).

For each of the subtasks in the discovery version, the students were provided with two exemplars to analyse and abstract the implicit pattern in the letter or number series and fill in the next set of letters or numbers; in the expository version, the implicit patterns were pointed out to the students with examples. The learning outcomes in these two learning tasks were assessed by means of a further set of problems, three for each subtask, to which the subjects applied the rules learned in a direct manner. These post-learning tasks were given in the same learning booklet. A copy of this booklet is attached in Appendix B.3.

v) Sum of Odd-Numbers Series Task

This mathematics task was adopted from the words of Kersh (1958, 1962). It concerned finding the relationship between the number of members in an odd-number series beginning with one and the sum of the series, i.e. the rule that the sum of an odd-number series beginning with one is equal to the square of the number of members in the series (e.g. $1,3,5,7,9 = 5^2 = 25$).

This learning task was presented in two forms in both the discovery and expository versions. In the discovery version it was first presented as a straight problem. If the subject was unable to solve the problem he was directed to the second form where the odd-number series were re-presented diagrammatically. The same three exemplars were used in each version. In the expository version, the underlying rule governing the sum of odd-number series beginning with one was given to the subject and it was explained using both forms of presentation as used in the discovery version.

The learning outcome was measured by the subjects' level of performance in a further set of problems presented within the learning booklet itself. A copy of this booklet is attached in Appendix B.4.

The assessment of learning outcomes - scoring procedure

One mark was given to each problem solved correctly except in the case of tasks where the students were required to state the rules learned in the learning unit (scrambled words task, coded words task). In the case of the latter, a score of two points was given for a clear and correct statement of the rule, a score of one for a partially correct statement and zero points for incorrect or no statements of rule. Also, since the nature of the three post-learning tasks (statement of rules, direct application of rules and inverse application of rules) involved in the case of the scrambled words task and coded words task was different, separate scores were obtained for the three subtasks.

3.42 The Phase II study learning tasks

As stated earlier, four units of chemistry learning material were developed for the Phase II study. In the design of these learning units, a number of factors had to be taken into account. The schools involved in the study had agreed to make available only four double periods for the investigation. Within these periods, the chemistry learning experience and two tests, namely the Hidden Figures Test and AH4 General Intelligence Test, had to be administered. Also, the investigation had to be carried out in the first term of the school year 1979 - 1980. This meant that the topic for study had to be selected from the early sections of the fourth form chemistry course for which the students had the necessary background knowledge to benefit from the lessons. Following discussions with the teachers concerned, one area of the course was identified which lent itself for presentation in a "programmed learning" format and which did not involve practical work. It concerned the combining powers of elements in relation to their position in the table, and the stoichiometry and formulae of compounds. The teachers assured the author that the students had the necessary background knowledge (concept of atom, molecule, combining power, Periodic table, etc.) to be able to follow the learning activities concerning the above themes. No separate attempt was made to assess the level of students' background knowledge as this would have taken up an undue proportion of the time allowed for the investigation. It should be noted, though, that all the students in the sample had chosen to study chemistry as an O-Level GCE Subject.

The design of the learning units was conducted as follows. First, the area selected was analysed to identify the main chemical ideas. Eight chemical ideas were identified which were then arranged into four learning units. As in the Phase I study, the learning units were developed in a self-instructional format, using in each case a discovery version and an expository version. The discovery format required students to identify a pattern of rule from a set of information in which the pattern or rule was implicit, whereas in the expository format the pattern or rule was given to the students, with illustrative examples and explanations.

The learning outcome from each of these learning units was assessed by appropriate direct and extension tasks provided within the learning booklets. Together with the learning units, the students were also provided with a copy of the Periodic Table of elements and a partly filled table of combining powers of elements and radicals to help them do the required learning activities. Additionally, since the principles learned in one learning unit had to be carried forward to the next units, at the end of each unit of learning the students were given a summary sheet of the main ideas in the unit. Copies of the four chemistry learning units, the data sheets and the summary sheets are given in

Appendix B.5.

In the following subsections, the learning activities and the post learning tasks involved in each unit are described in detail.

a) UNIT 1 Relationship between combining power and group number of an element

In this unit, the students were required to learn the relationship between the combining power and the group number of the element in the Periodic Table. This is that the combining power of an element in group 1,2,3 or 4 is equal to the group number, and the combining power of an element in group 5,6 or 7 is equal to 8 minus the group number.

In the discovery version lists of names of elements were provided in tables. The students were required to complete the tables by filling in the combining power and the group number of the elements (with the help of the data sheets provided) and then to abstract from the completed tables the implicit relationship between the combining power and the group number of elements. In the expository versions the relationship between the combining power of an element and its group number was given to the students, together with illustrative examples.

The learning outcome from this learning unit was assessed by two tasks. The first task involved the application of the principle learned in the unit to a further set of problems, and the second involved the assessment of the awareness of the change in relationship between combining power and the group number as the group number increased. It should be noted that this is in itself a discovery task because it required the student to have gained an insight beyond the mere knowledge of the relationship between combining power and group number of an element.

b) UNIT 2 Formulae of binary compounds

In this unit, the students were first exposed to the idea that a chemical compound consists of a metallic component and a non-metallic component. In the discovery version, the students were required to discover that in a balanced chemical formula of a compound the total combining power of the metallic component is equal to the total combining power of the non-metallic component. For this purpose, they were provided with a table giving the formulae of seven binary compounds and asked to calculate the total combining power of the metallic and non-metallic component of each compound and, from this, abstract the implicit principle. In the expository version, the chemical principle involved was presented to the students in an explicit form, again with illustrative examples.

The learning outcome was assessed by requiring the students to apply the principle learned in the unit to work out and write chemical formulae of (i) a set of normal compounds (6 items) and (ii) a set of hypothetical compounds (6 items).

c) UNIT 3 Combining powers of radicals and formulae of compounds containing radicals

In this unit, the students were first introduced to two chemical ideas, namely (i) that a radical is a group of atoms that always stays together in a chemical compound and (ii) that the group of atoms which constitutes a radical may be considered to be a single unit, when writing chemical formulae. Then, in the discovery version, students were required to find out that the combining power of a radical in a compound can be worked out by dividing the total combining power of the metallic component by the number of units of radicals present in the compound. For this purpose, they were provided with six exemplars to work on. In the expository version the above idea was explicitly stated and illustrated with appropriate examples.

The learning outcome was assessed by means of a further set of similar problems to which the students applied the principle learned in a direct manner. Besides this, another set of problems was provided to which the students applied the principles learned in this unit and in the earlier units to work out, to write chemical formulae of (a) normal compounds and (b) hypothetical compounds containing radicals. This exercise was included mainly to make the learning experience valid, complete and meaningful in the context of the chemistry course which the students were following.

d) <u>UNIT 4</u> <u>Combining power of transition metals and their compounds</u>

In this unit, the students learned (i) that the transition metals can have more than one combining power in their compounds and (ii) that the combining power of a transition metal in a compound is indicated in the chemical name of the compound by a roman numeral. For this purpose, the chemical names of ten transition metal compounds and their formulae were provided in the discovery version for the students to work on and identify the principles involved. In the expository version, these principles were pointed out to the students, and amplified with appropriate examples.

The learning outcome was assessed by requiring the students to apply the principles learned in order (i) to deduce the combining power of transition metals from the chemical names of the compounds and (ii) to work out combining power of the transition metal in a compound and write the chemical name of the compound. Further to this, they also worked out and wrote chemical formulae of a set of transition metal compounds by applying principles learned in earlier unit as in unit 3. This latter exercise was included for the same reason as stated earlier.

<u>The assessment of learning outcomes - scoring procedure</u>

As in the case of the Phase I study, one mark was given to each problem solved correctly. However, in some problems subtasks were involved (e.g. in the working out and writing of chemical formula of a compound, the student was first required to work out the ratio of atoms and/or radicals involved in the compound before writing the chemical formula); in such cases the subtasks were scored separately so as not to penalise the students completely for errors in subparts of the problems.

The final versions of all learning units were validated and judged to be unambiguous in both content and presentation by two external judges.

3.5 THE STUDY SAMPLE

The samples for the two phases of the study were drawn from students enrolled in four large comprehensive schools for two consecutive years as third and fourth formers. The samples were opportunity samples in the sense that they were obtained by directly contacting the Head teacher of the respective school with the help of people with contact in the Department. The samples are described below.

3.51 The Phase I study sample

The student sample for the Phase I study consisted of 318 third-formers from the four schools. They were all members of the top and middle band classes in their schools. Of these 152 were boys and 166 were girls. The average age of the sample was 14 years and 4 months. The distribution of the sample among the schools is given in Table 3.1.

3.52 The Phase II study sample

This study involved 127 fourth formers (from three of the four schools involved in the Phase I study) who had elected to study chemistry or physical science as one of their "O" level examination subjects. Of these, 87 were students who had taken part in the Phase I study. The distribution of the sample among the schools is given in Table 3.2.

TABLE 3.1 THE STUDENT SAMPLE FOR THE PHASE I STUDY

SCHOOL	BAND (No. of classes)	Number of Students		
		MALE	FEMALE	TOTAL
1	TOP (4)	50	70	120
2	TOP (1)	13	16	29
	MIDDLE (2)	30	27	57
3	MIDDLE (1)	15	15	30
4	TOP (2)	26	26	52
	MIDDLE (1)	18	12	30
ALL	TOTAL	152	166	318

TABLE 3.2 THE STUDENT SAMPLE FOR THE PHASE II STUDY

SCHOOL	Number of Students		
	MALE	FEMALE	TOTAL
1	29	8	37
2	21	26	47
4	30	13	43
TOTAL	80	47	127

3.6 ADMINISTRATIVE ARRANGEMENTS

3.61 The Phase I study

The Phase I study involved the administration of five learning tasks, four cognitive styles test and the preference-for-learning-types inventory. These were administered over a span of nine weeks during the last term of the school year 1978 - 1979. Not all the tests and learning tasks could be administered to all the students in the four schools, because of variations in the amount of time allowed for participation by students in this study. An attempt was made to ensure that each student completed at least two of the cognitive styles tests, two of the learning tasks (one in the discovery version and the other in the expository version) and the preference-for-learning-types inventory. Table 3.3 shows the distribution of tests and learning tasks among the sample.

In general, the learning tasks and cognitive styles tests were administered alternately. Also, the discovery version and expository version of the learning tasks were alternated, i.e. a student who had done the discovery version of one task was given the expository version of the next task, and so on. All the administration of the tests and learning tasks was carried out by the author himself. In general, one teaching period (35 minutes) was allocated for each of the learning tasks. Each of the cognitive styles test and the preference inventory required about 20 to 35 minutes for administration. For three of the cognitive styles tests (Conceptual Preference Test, Objects Sorting Test, Uses of Objects Test) no time limit was imposed, but students were requested to complete the task by the end of the class period.

3.62 The Phase II study

For this, four double periods over two to four weeks were used in each

TABLE 3.3 DISTRIBUTION OF TESTS AND LEARNING TASKS AMONG THE SAMPLE

SCHOOL	CLASS	COGNITIVE STYLE TESTS				LEARNING TASKS				PLT
		CST	CPT	OST	UOBT	SWT	CWT	LNS	SONS	
1	1	x	x	x	x	x	x	x	x	x
	2	x	x	x	x	x	x	x	x	x
	3	x	x	x	x	x	x	x	x	x
	4	x	x	x	x	x	x	x	x	x
2	1	x	x	x			x	x		x
	2	x	x	x		x	x		x	x
	3	x	x	x	x	x			x	x
3	1	x		x	x	x	x			
4	1	x			x		x		x	x
	2	x			x		x		x	x
	3	x			x	x		x		x

CST - Concealed Shapes Test
CPT - Conceptual Preference Test
OST - Objects Sorting Test
UOBT - Uses of Objects Test
SWT - Scrambled Words Task
CWT - Coded Words Task
LNS - Letter Series and Number Series Tasks
SONS - Sum of Odd-Numbers Series Task
PLT - Preference for Learning Types Inventory

of the schools. The "field work" took place during the first term of the 1979 - 1980 school year. As in Phase I, the discovery and expository versions of the chemistry learning units were assigned to the classes on an alternate basis, i.e. a class which had done the discovery version of unit 1, was given the expository version of unit 2, and so on. The two ancillary tests (the Hidden Figures Test and the AH4 test) were administered to the classes when they did the expository versions of the learning units, as these required less time to complete than the discovery learning tasks. In addition and when time permitted, students who had not taken part in the Phase I study, were encouraged to complete some of the cognitive styles tests used in the Phase I study.

At the end of Phase II study, special arrangements were made with each school for the administration of the reflectivity-impulsivity test. This was necessary because this test had to be administered on a one-to-one basis and required a total administration period of three days for each school. Regrettably, students from only two schools were able to complete this test.

Figure 3.3 summaries the administrative arrangements of the total investigation.

SCHOOL YEAR

1978-1979

↓

Phase I Study

Boys and girls in the third year top and middle sets of four Comprehensive Secondary School (N=318)

↓

Random administration of learning tasks, alternately in the discovery and expository form, to students.

(i) Scrambled words task

(ii) Coded words task

(iii) Letter and Number Series

(iv) Sum of Odd-Number Series

↓

Cognitive styles tests administered between learning tasks.

(i) Concealed Shapes Test

(ii) Conceptual Preference Test

(iii) Objects Sorting Test

(iv) Uses of Objects Test

↓

Ancillary test - Preference-for-learning-types inventory administered at the end.

subset →

SCHOOL YEAR

1979-1980

↓

Phase II Study

Boys and girls in the fourth year Chemistry sets in three of the same schools (N=127)

↓

Random administration of chemistry learning units to classes, alternately in the discovery and expository format.

↓

Administration of the Hidden Figures test between learning units

↓

Administration of the ancillary test - AH4 Test of General Intelligence between learning units

↓

individual administration of the Matching Familiar Figures Test (Reflectivity-impulsivity measure) after completion of the foregoing units and tests.

Figure 3.3 Summary of the administration of the total investigation

CHAPTER 4 PERFORMANCE OF TESTS AND OTHER MEASURES

4.0 INTRODUCTION

In this chapter, the performance of the cognitive style tests and other measures is examined. In part I of the chapter, the characteristics of the tests themselves are reported, with particular reference to the facilities of items and overall facilities, item-total score correlations and reliabilities, whilst in part II the relationships between the tests, are explored. This is done by means of correlational analyses and factor analysis.

PART I THE PERFORMANCE OF COGNITIVE STYLES TESTS AND ANCILLARY MEASURES

4.1 FIELD INDEPENDENCE/DEPENDENCE MEASURES

As previously pointed out, this cognitive style was measured by means of two tests, the Concealed Shapes Test (Satterley and Telfer 1979) and the Hidden Figures Test (Kempa and Cox 1976). Both tests were described in detail in Chapter 3, as was the scoring procedure adopted for their evaluation. A feature of this was the separate scoring of "present" and "absent" items.

4.11 Concealed Shapes Subtests

The Concealed Shapes Test was taken by 344 students. Ninety-two per cent of the students completed the test within the time allowed. The performance of each of the subtests are described below.

a) "Present" items subtest. Facility indices and the item-total score correlations were calculated for the 51 items in the "present" items subtest. The results are given in Table C.1, Appendix C. The mean facility of the subtest was found to be 0.745, with facility indices ranging from 0.21 to 0.98. Only two items had facility below

below 0.40 and eleven items above the 0.90 level. Most of the latter items are located in the early part of the test.

The item-total score correlation of the "present" items ranged from 0.06 to 0.41, with four of the items having correlation coefficients below 0.10. Normally, these low coefficients would have suggested the deletion of the items. However, since the test had previously been used and validated in the context of other studies, it was decided to use the full test (51 items) in the present study. The Cronbach alpha reliability of the "present" subtest was 0.820.

b) <u>"Absent" items subtest</u>. The facility indices and the item-total score correlations for the 45 items in the "absent" items subtest are given in Table C.2, Appendix C.

The facility indices for items in this subtest ranged from 0.41 to 0.97, with a mean item facility of 0.830. Nearly half of the items had facility values in excess of 0.90 but were retained in order to leave the test intact (see comment above).

The item-total score correlations of all items, with the exception of item 15, fell between 0.05 and 0.43. Item 15 had a significant negative correlation (-0.24) with total score and was not taken into consideration in the final scoring of the test. The removal of this item improved the alpha reliability coefficient of the subtest from 0.784 to 0.803.

4.12 Hidden Figures Subtests

The Hidden Figures Test was administered to 124 students. Eighty seven per cent of the students completed the test within the time allowed. The performance of each of the subtests is described below.

a) <u>"Present" items subtest.</u> The facilities of the items in this subtest ranged from 0.29 to 0.97. Details are given in Table C.3, Appendix C. Only four items were found to have facilities below 0.40 with one item having a facility index above the 0.90 level. The average facility of the test was 0.616.

The item-total score correlations of the items ranged from 0.07 to 0.34, with all but one item having an item-total score correlation above 0.10. The removal of this item from the test did not significantly improve the reliability of the subtest and was therefore retained. The alpha reliability coefficient of the subtest was 0.590.

The relatively low reliability of the "Present" subtest of the HFT is largely a reflection of the shortness of the test: it contains only 18 items. Using the Spearman-Brown formula for estimating the (theoretical) reliability of an equivalent 51 item test (which is the length of the comparable subtest of the Concealed Shapes Test), a reliability value of 0.803 was obtained. This indicates that the HFT "Present" subtest was no less reliable than the corresponding Concealed Shapes "present" subtest for which the reliability was 0.820.

b) <u>"Absent" items subtest.</u> The facility indices and the item-total correlations of the 30 items in this subtest are reported in Table C.4, Appendix C. The item facilities of this subtest items ranged from 0.21 to 0.97, with two of items having facilities below 0.40 and the facilities of 9 items lying above 0.90. Most of these occur in the first half of the test. The mean facility of the subtest was found to be 0.793.

The item-total score correlation for all items, with the exception of item 5, fell between 0.09 and 0.58 with most items having values above 0.25. Item 5 showed a negative correlation with the total score and was removed from the test. The alpha reliability coefficient of the reduced 29 items subtest was 0.832.

4.2 CONCEPTUALISATION STYLES MEASURES

In the present study the leaning of individuals towards the different conceptualisation styles was assessed by analysing (i) the reasons for the grouping of objects together in the Object Sorting Test and (ii) the responses to the specially designed Sigel type Conceptual Preference test. The tests and the scoring procedures adopted for them were described in Chapter 3. The Object Sorting Test was administered to 250 students and the Sigel type Conceptual Preference Test to 189 students. These two tests give rise to three scales each:- relational, descriptive and inferential. The performance of each of these two tests is described below.

4.21 Object Sorting Test

The reasons for putting objects together in specific groups were first judged to be relational, descriptive or inferential with the help of a classification scheme. The raw scores obtained were then converted to percentage scores for the reasons stated in Chapter 3. The performance of the test is shown in Table 4.1 below.

TABLE 4.1 PERFORMANCE OF OBJECTS SORTING TEST (CONCEPTUALISATION STYLES)

Conceptualisation Style	Percentage Score Range	Mean Percentage Score	Std. Dev.
Relational	0 - 56	16.82	11.31
Descriptive	0 - 100	15.05	14.29
Inferential	0 - 100	67.69	14.52

It can be seen from the table that the test produced a high preference for responses expressing the inferential conceptualisation style, whilst the reäponses expressing the descriptive and relational modes of conceptualisation were found relatively unattractive. The percentage scores for the inferential, descriptive and relational modes were in the ratio 68 : 15 : 17, which is in good agreement with the result obtained by Wallach and Kogan (1965:125) they reported the corresponding percentage ratios to be 56.13 : 20.41 : 23.41 for boys and 59.79 : 14.85 : 25.42 for girls.

4.22 Conceptual Preference Test

As has previously been stated (Chapter 3), this test gives rise to three ipsative scores, for the relational, descriptive and inferential modes, each within a score range from 24 to 72. The performance of each item and the overall performance of each scale is described below.

i) Relational Scale

The item mean scores and the item-total score correlations for the 24 inferential items are given in Table C.5, Appendix C. The item mean scores range from 1.29 to 2.67 (Max=3, Min=1). The overall item mean score is 1.82, which is entirely satisfactory.

The item-total score correlations of the items range from 0.12 to 0.52, with only two of the items having a value of less than 0.20. This suggests that the "Relational" subscale of the Conceptual Preference Test has an acceptable internal consistency. This is further confirmed by the Cronbach alpha reliability coefficient for the scale which was found to be 0.799.

ii) Descriptive Scale

The item mean scores and item-total score correlations for the 24 descriptive items are listed in Table C.6, Appendix C. The item mean scores range from 1.22 to 2.25 (Max=3, Min=1) with the overall item mean score of 1.66. This indicates that the descriptive statements have in general attracted less "most preferred" responses than relational statements (mean score 1.82).

The item-total score correlations of all items range from 0.05 to 0.48, with four items having values below 0.20. Of these item 5 is clearly the weakest with a value of only 0.054. Since the item proved satisfactory on the other two scales of the Conceptual Preference Test, it was retained, rather than rejected. The alpha reliability coefficient of the scale was found to be 0.741. Hence, the scale can be considered a reliable measure of the preference for 'descriptive' conceptualisation.

iii) <u>Inferential Scale</u>

The item mean score and the item-total score correlation for the 24 inferential items are given in Table C.7, Appendix C. The item mean scores fall within the range 1.74 to 2.84, with an overall item mean score of 2.50. As was previously noted for the Object Sorting Test, there is a generally high preference for the inferential mode of conceptualisation, and this is in evidence in this test also. The ratio of the overall item mean scores is 2.50 : 1.66 : 1.82, for inferential, descriptive and relational responses respectively.

The item-total score correlations of the items ranged from 0.02 to 0.54, with only three items having item-total score correlations below the 0.20 level. The "weakest item," both in terms of its mean score and its correlation with the total score was item 11. It was recognised, with hindsight, that the inferential statement in this item might well be construed as a descriptive one, and this may explain its unsatisfactory performance on this scale. The alpha reliability coefficient of the inferential scale worked out to be 0.798. In the overall sense, the scale may hence be considered a reliable measure of the preference for inferential categorisation.

4.3 CONCEPTUAL DIFFERENTIATION MEASURE

Students' conceptual differentiation behaviour was assessed by the Objects Sorting Test. The main concern here was with the number of groups formed by a student which contains two or more objects. This measure was obtained for 250 students.

The minimum score obtained by the test sample was 2 and the maximum score was 25. The mean score and standard deviation were 14.76 and 4.45, respectively. This would suggest an adequate differentiation between "high" and "low" conceptual differentiators.

4.4 CONVERGENCY-DIVERGENCY MEASURES

The convergent and divergent thinking traits of students were assessed by means of the Uses of Objects Test previously described in Chapter 3. As was also mentioned there, the test (which was administered to 249 students) gave rise to two scores for each student: a "fluency" score and a "flexibility" score. The performance of the test, in terms of these two score types, is examined below.

4.41 Fluency Score

The item mean scores and the item-total score correlations are prescribed in Table C.8, Appendix C. The six items in the test produced mean scores ranging from 3.59 to 7.38. "Newspaper" as an item gave rise to the largest number of uses (mean score = 7.38), while "paperclip" and "cork" seemed to pose some difficulty (mean scores = 3.59 and 3.76 respectively). The overall (average) mean item score was 4.98.

Item-total score correlations ranged from 0.47 to 0.63, indicating a satisfactory and consistent performance of each item as part of the fluency scale. The alpha reliability coefficient of the scale was found to be 0.830, which too is a satisfactory value.

4.42 Flexibility Score

The item mean scores and the item-total score correlations for the six items on the flexibility scale are also shown in Table C.8, Appendix C. The item mean scores on this scale ranged from 2.59 to 5.01. Again, "newspaper" was the item which gave rise to the largest number of different classes of use, whilst "paperclip" and "cork" produced the lowest numbers. Simple inspection of scores obtained by students suggested that fluency and flexibility scores are highly correlated with each other. This is examined in detail in part II of this Chapter.

The item-total score correlations of the six items ranged from 0.46 to 0.52, indicating a moderately high internal consistency in the performance of the items. The alpha reliability coefficient of the scale was 0.736.

4.5 REFLECTIVITY-IMPULSIVITY MEASURES

This cognitive style was measured by the Matching Familiar Figures Test, previously described in Chapter 3. This test was administered to altogether 78 students. Two scores were obtained for each subjects, viz. the mean response time to the subject's first hypothesis on each of the 20 items, and the total number of errors on the 20 items. The performance of the two scales, mean response time and error scores are described below.

4.51 Mean Response Time Scale

Table C.9 in Appendix C presents the mean response time, standard deviation and the item-total score correlation for the 20 items in the Matching Familiar Figures Test. The mean response time of the 20 items ranged from 8.42 seconds to 19.58 seconds and the standard deviations in the range from 3.92 to 17.87 seconds. The latter values indicate that all the items had a good spread of response times, and this should help in the discrimination between reflective and impulsive subjects. The overall mean response time per item was found to be 13.35 seconds.

The item-total score correlations of the 20 items ranged from 0.54 to 0.88, which indicates that all the items behaved fairly consistently in terms of the responses which they attracted. The alpha reliability coefficient of the whole scale was 0.956.

4.52 Error Score Scale

Table C.9 in Appendix C also lists the mean error score, standard deviation and the item-total score correlation of the error scores derived from the Matching Familiar Figures Test. The mean error score of the 20 items ranged from 0.09 to 1.10, with an average of 0.47. The standard deviations of the mean error score of the items ranged from 0.29 to 1.22.

Generally, the item-total score correlations of the items were low; they ranged from -0.04 to 0.41, with nine of the items having item-total score correlations of less than 0.20. The alpha reliability of the test, when evaluated in terms of the error scores, was also found to be only moderate ; a value of 0.59 was determined. Although the results of the item analysis would have justified the removal or modification of a few of the items, no such adjustments were made in order to retain the test in the format in which it had been designed and validated by the original authors (Cairns and Cammock, 1978).

4.6 AH4 GENERAL INTELLIGENCE TEST

This test was administered to 119 subjects who took part in the main study relating to chemistry learning. For reasons given in Chapter 3 three separate scores were derived from this test although the manual for the test makes no mention of any significance to be attached to the subtests separately. The three scores derived were, AH4 Part I, "verbal and numerical reasoning" score, AH4 Part II, "spatial reasoning" score and total score. The performance of each part of the test is given in Table 4.2.

TABLE 4.2 PERFORMANCE OF AH4 GENERAL INTELLIGENCE TEST

Subtests	Max. Score	Score Range	Mean Score	Std. Dev.
PART I	65	19 - 62	38.35	6.35
PART II	65	32 - 64	51.79	7.14
TOTAL	130	57 - 123	90.25	11.21

The norm reported for the total score in the handbook for this test are:

Student type	Mean Score	Std. Dev.
Grammar School children, 14 years old (N=533)	85.26	11.21
Secondary Modern School children, 14 years old (N=565)	59.51	19.50

The sample in the present study seemed more alike in IQ to Grammar School children. This is not surprising as the present sample (N = 119) was a selected group from the top band of three Comprehensive Schools.

4.7 PREFERENCE FOR LEARNING TYPES INVENTORY

The preference for discovery and expository learning was assessed as stated in Chapter 3 by means of a 12-item semantic differential instrument. The inventory was administered to 275 students at the end of the Phase I study. The instrument incorporated two scales measuring two separate constructs : ease/difficulty of a type of learning and enjoyment of/dislike for a type of learning. To examine the internal consistency of the two scales, appropriate item-total score correlations were calculated with respect to both learning types. The results are given in Table C.10, Appendix C.

It is seen from there that five of the six items in the Ease/Difficulty scale produced item-total score correlations of above 0.60, for both discovery learning and expository learning. The one item not producing a satisfactory correlation was the "demanding-undemanding" one, possibly because of students' relative unfamiliarity with this set of terms and its meaning. In view of the unsatisfactory performance of this item, it was removed from the Ease/Difficulty scale. The resulting reduced scale showed a reliability of 0.874 and 0.923, for the discovery and the expository learning modes, respectively. The item-total score correlations of all the six items in the Enjoyment/Dislike scale are fairly high for both types of learning, ranging from 0.417 to 0.777. The scale consistency is thus entirely satisfactory. Likewise, the alpha reliability coefficients for the whole scale were found to be 0.844 and 0.818, respectively, for the discovery learning and expository learning. Again, these are satisfactory values.

PART II

In this part of the chapter, the relationship between the various tests used in the study is examined. This is done in order to investigate the independence of the tests with respect to one another and also to examine the relationship between the various cognitive styles measures used and IQ. This is done by means of correlational analyses and a factor analytic procedure.

4.8 CORRELATIONAL ANALYSES

Correlational analyses were performed to examine the relationship between all the tests and subtests described in Part I of this chapter. Table 4.3 reports the product-moment correlations between the various measures. The relationships between the various cognitive styles and other measures are discussed in the following separate subsections.

4.81 Field independence/dependence tests

a) Correlation between subtests

It will be remembered that in the scoring procedure used for the two field independence/dependence measures, separate "present" and "absent" scores were obtained. This was in contrast to the usual practice where "present" and "absent" scores are treated as additive, i.e. uni-dimensional. The correlation between "present" and "absent" scores was found to be 0.411 (Concealed Shapes) and 0.467 (Hidden Figures). Although both are statistically significant they are far from high. The conclusion must be reached, therefore, that the uni-dimensionally of "present" and "absent" scores is not established experimentally and that the two scores should, in the strict sense, not be treated as additive scores.

Unfortunately, no independent administration of other field independence/ dependence test was possible, e.g. of the Rod-and-Frame Test or the Body Adjustment Test which are generally considered to be the "primary" measures of this cognitive style. Consequently, no judgement can be made as to whether the "present" or the "absent" scores represent the better correlates to these primary measures. The decision was taken, for the purpose of the present study, to accept the "present" items subtests scores as the operational criterion measures of field independence/dependence, as they approximate more to the original Witkin Embedded Figures Test where the subject is required to abstract a simple

TABLE 4.3 PEARSON PRODUCT-MOMENT CORRELATIONS AMONG COGNITIVE STYLES VARIABLES AND IQ

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Field independence/dependence (CST - "Present" items)	-																
2. Field independence/dependence (CST - "Absent" items)	0.411 N=344	-															
3. Field independence/dependence (HFT - "Present" items)	0.432 N=122	0.148 N=122	-														
4. Field independence/dependence (HFT - "Absent" items)	0.178 N=122	0.159 N=122	0.467 N=124	-													
5. Preference for inferential concept (CPT)	0.053 N=188	0.065 N=188	0.049 N=47	-0.040 N=47	-												
6. Preference for descriptive concepts (CPT)	0.093 N=188	0.054 N=188	0.207 N=47	0.181 N=47	-0.392 N=189	-											
7. Preference for relational concepts (CPT)	-0.132 N=118	-0.089 N=188	-0.239 N=47	-0.122 N=47	-0.568 N=189	-0.511 N=189	-										
8. Percentage inferential concepts (OST)	0.000 N=217	0.006 N=217	0.104 N=76	0.102 N=76	0.044 N=185	0.085 N=185	-0.122 N=185	-									
9. Percentage descriptive concepts (OST)	-0.024 N=217	0.074 N=217	-0.171 N=76	-0.130 N=76	-0.092 N=185	0.044 N=185	0.052 N=185	-0.676 N=221	-								
10. Percentage relational concepts (OST)	0.032 N=217	0.026 N=217	0.104 N=76	0.029 N=76	0.072 N=185	-0.139 N=185	0.053 N=185	-0.387 N=221	-0.386 N=221	-							
11. Conceptual differentiation	0.001 N=217	0.079 N=217	0.105 N=76	0.057 N=76	0.101 N=185	-0.111 N=185	0.024 N=185	-0.011 N=221	-0.132 N=221	0.174 N=119	-						
12. Convergency-divergency (fluency-score)	0.061 N=245	-0.082 N=245	-0.038 N=80	-0.178 N=80	-0.068 N=144	0.019 N=144	0.050 N=144	-0.048 N=173	0.036 N=173	0.021 N=173	0.100 N=173	-					
13. Convergency-divergency (flexibility score)	0.050 N=245	-0.004 N=245	-0.061 N=80	-0.081 N=80	-0.132 N=144	0.098 N=144	0.034 N=144	-0.049 N=173	-0.022 N=173	0.070 N=173	-0.142 N=173	0.738 N=249	-				
14. Reflectivity-impulsivity (mean response time)	0.148 N=76	0.236 N=76	0.163 N=77	0.219 N=77	-0.004 N=31	0.099 N=31	-0.084 N=31	0.116 N=38	0.052 N=38	-0.193 N=38	-0.105 N=38	0.060 N=62	-0.003 N=62	-			
15. Reflectivity-impulsivity (error score)	-0.106 N=76	-0.088 N=76	-0.179 N=77	-0.120 N=77	-0.225 N=31	0.224 N=31	0.087 N=31	-0.009 N=38	-0.230 N=38	0.258 N=38	-0.012 N=38	-0.058 N=62	0.077 N=62	-0.600 N=78	-		
16. AH4 Part I	0.136 N=119	0.095 N=119	0.118 N=116	0.049 N=116	0.201 N=45	-0.020 N=45	-0.182 N=45	-0.003 N=73	-0.186 N=73	0.233 N=73	0.048 N=73	0.162 N=77	0.082 N=77	-0.065 N=72	0.023 N=72	-	
17. AH4 Part II	0.372 N=119	0.386 N=119	0.199 N=116	0.218 N=116	0.200 N=45	0.111 N=45	-0.319 N=45	0.188 N=73	-0.202 N=73	0.005 N=73	0.121 N=73	0.074 N=77	0.035 N=77	-0.088 N=72	0.031 N=72	0.343 N=119	-
18. AH4 Total Score	0.316 N=119	0.301 N=119	0.195 N=116	0.169 N=116	0.246 N=45	0.061 N=45	-0.314 N=45	0.118 N=73	-0.230 N=73	0.131 N=73	0.103 N=73	0.145 N=77	0.072 N=77	-0.097 N=72	0.034 N=72	0.801 N=119	0.837 N=119

- - - $p \leq 0.05$; _ __ $p \leq 0.01$ ____ $p < 0.001$

figure from a complex figure. Comparison between the "present" scores on the Concealed Shapes Test and the Hidden Figures Test, produces only a moderately high correlation ($r = 0.432$, $p<0.001$), indicating that the two measures have only limited concurrent validity.

b) <u>Correlation between field independence/dependence measures and IQ</u>

Concealed Shapes Test scores show a fairly high correlation with AH4, total score ($r = 0.316$ and $r = 0.301$, for "Present" and "Absent" scores, respectively). Both correlation coefficients are significant at the $p=0.001$ level. The cause of this would seem to lie in the nature of the items in Part II of the AH4 test which are concerned with "spatial reasoning". The correlations of the Concealed Shapes subtests scores with AH4/Part II scores are 0.372 and 0.386, respectively. The corresponding correlations for the Hidden Figures Test are distinctly lower, 0.195 and 0.169, for "present" and "absent" score, with the AH4 total score, and 0.199 and 0.219 for the Part II AH4 scores. Only three of these correlation coefficients reach the 5% significance level. It is thus evident that the Hidden Figures Test is less IQ biased than the Concealed Shapes Test.

The existence of positive correlations between the field independence/ dependence measures and the AH4 scores gives rise to two different interpretations. One is that field independence/dependence as a cognitive style has a distinct IQ component (this would at least qualitatively be in line with the classification of field independence/ dependence as a Type I cognitive style, Kogan's classification (Chapter 2). This, in turn would render this style into one which should have a major bearing on students' intellectual performance. The other, alternative interpretation is that the two instruments used for the measurement of field independence/dependence employ items which are not unlike those found in spatial ability parts of IQ tests, and that this gives rise to the positive correlation.

Of the two different interpretations, the second one is preferred here for the reason that the Concealed Shapes Test (which uses figures and representations more akin to those in the AH4 test) produces a higher positive correlation with Part II/AH4 than does the Hidden Figures Test (which employs only straight line drawings).

Whatever the actual reason may be for the positive correlations observed between the field independence scores and the AH4 scores, an important consequence of the finding is that any evaluation of students' learning performance in relation to their field independence or dependence, the possible influence of IQ must be acknowledged.

c) Correlations between field independence/dependence measures and other cognitive style measures

Although the correlation between the average response time scores derived from the Matching Familiar Figures Test and the scores on the "absent" part of Concealed Shapes Test is found to be statistically significant, the correlation itself is low ($r = 0.236$; $p = 0.05$). The corresponding correlations between the "absent" part of the Hidden Figures Test just fails to reach significant level ($r = 0.219$, $p = 0.055$). This lowish, positive correlation between these two sets of variables suggests that the performance on the Concealed Shapes Test is to some extent influenced by the reflective nature of the students. Interestingly, this affects "absent" items far more than "present" items on the two field dependence tests. Again, this supports the view that abstraction of a simple figure from a complex figure involves a different cognitive process to that of the reporting of absence of a stimulus figure in a complex figure.

None of the other correlation coefficients between the scores on either the Concealed Shapes Test or the Hidden Figures Test and other cognitive styles measures was found to be high enough to reach statistical significance, indicating that the Concealed Shapes Test and the Hidden Figures Test are independent of any of the other cognitive styles measures (conceptualisation styles, conceptual differentiation, convergency/divergency).

4.82 <u>Conceptualisation Styles</u>

a) <u>Correlations between the scores in the two alternative measures of conceptualisation styles</u>

It will be remembered that the conceptualisation styles were measured by two different tests, the Conceptual Preference Test, and the Object Sorting Test. As stated earlier, the Conceptual Preference Test gives rise to three ipsative scales, inferential, descriptive and relational. Hicks (1970) has demonstrated that random ipsative scores on a three item test automatically give correlation coefficients of -0.50. However, if the data are non-random, it is found that this r = -0.50 base is flexible. In the present study the correlations between the inferential scale and the other two scales, descriptive and relational are r = -0.392 and r = -0.568, respectively and the correlation between the descriptive and the relational scale is -0.511. No significance can be attached to these observations because as stated earlier the scores on these scales are interrelated and a correlational analysis on the data is strictly not appropriate. However, the corresponding correlations between scores from the Object Sorting Test (which are normative) also show a similar pattern. Scores for inferential sorting are negatively correlated to both descriptive and relational sorting scores (r = -0.676 and -0.387, respectively); descriptive sorting scores are also negatively correlated to relational sorting scores (r = -0.386). This would indicate that the ipsative scales of the Conceptual Preference Test are not an invalid measure of conceptualisation styles, despite their ipsative nature.

Although the tests have been claimed to measure the same cognitive styles, in the present study the relationships between the corresponding scales of the two tests are found to be rather low:-

Scales	Correlation Coefficient: (N=185)
Inferential - inferential	0.044 (N.S)
Descriptive - descriptive	0.044 (N.S)
Relational - relational	0.053 (N.S)

It is evident from this that the two tests do not measure the same aspects of conceptualisation styles and therefore they cannot be treated as equivalent measures of the same cognitive styles. Since the Conceptual Preference Test has been used as the primary measure of conceptualisation styles in most of the definite studies into this cognitive style dimension (Kagan et al.), the scores on the fixed response Conceptual Preference Test were accepted in the present investigation as the key measure of the conceptualisation styles. Further discussion that follows in this section will concern only the scores on the Conceptual Preference Test.

b) Correlations between conceptualisation styles scores and IQ

Of the three conceptualisation styles, only the relational scale scores show a statistically significant correlation with IQ. This correlation is negative (-0.314), and indicates that students with high relational conceptualisation preference tend to score lowly on the AH4 test. It would appear that low IQ subjects find the relatively simple and overt relational links between simuli more appealing than links which are based on or involve part-stimuli which have first to be abstracted from the whole stimuli presented.

c) Correlation between conceptualisation styles scores and other cognitive styles

All the three conceptualisation styles scores have near zero correlation with the other cognitive styles examined in the present study. Hence, the conceptualisation styles as measured by the Conceptual Preference

Test can be considered as independent cognitive styles variables for the examination of learning performance in subsequent analyses.

4.83 Conceptual Differentiation Style

a) Correlation between conceptual differentiation scores and IQ scores

The conceptual differentiation style score denotes the number of groups formed by the student, that contain two or more objects shown on the Object Sorting Test. The correlation matrix shows that these scores have no correlation of any significance with IQ scores. This finding is in agreement with that reported by Gardner, Jackson and Messick (1960) who found correlations between the Object Sorting Test and the various ability indices used in their study to be uniformly non-significant.

b) Correlations between conceptual differentiation scores and other cognitive styles scores

Conceptual differentiation scores do not correlate significantly with scores derived from tests measuring the other cognitive styles variables examined in this study. The conceptual differentiation style is a genuinely independent cognitive style.

4.84 Convergency-divergency

a) Correlation between fluency scores and flexibility scores

As was mentioned in Chapter 3, two sets of scores were obtained from the Uses of Objects Test; these were identified as fluency scores and flexibility scores, respectively. The characteristics of these score have already been described in Chapter 3. The correlation coefficient between these two scores was found to be 0.738, which is statistically significant at the 0.1% level. This high correlation suggests that the two measures are based on a common underlying construct. This observation is in agreement with the findings of Hudson (1968) and of Vernon (1971) who also reported high correlation to exist between fluency and flexibility scores. For the purpose of the subsequent analyses of learning performance in relation to convergency, the flexibility score was selected as the criterion measure of convergency/divergency. This decision was made in the belief that divergent thinking manifests itself more in the production of different ideas as the result of spontaneous flexibility in the points of reference, rather than in the mere generation of a large number of essentially similar uses which are based on just one or two properties of an object.

b) Correlation between flexibility scores and IQ scores

The correlation matrix reveals no significant correlation to exist between the flexibility measure and IQ scores. This indicates that the ability to produce large number of ideas is not directly relatable to the subjects' IQ.

c) Correlation between flexibility scores and other cognitive styles

The convergent-divergent thinking style as measured by the flexibility score was found to be independent of the other cognitive styles constructs as there is no correlation of any significance between the flexibility score and scores in other cognitive styles tests.

4.85 Reflectivity-Impulsivity

a) Correlation between the time scores and error scores

The two measures of reflectivity-impulsivity, i.e. average response time and error scores on the Matching Familiar Figures Test, show a strong negative correlation with one another ($r=-0.60$, $p=0.001$). It appears the longer the subject delays his response, the smaller is the number of errors made by him. This observation is in agreement with the findings reported in literature (Kagan et al. 1964, 1966; Cairns 1977). The high correlation between these two scales suggests that they measure essentially the same construct. It would seem therefore adequate to consider only one of the scales in an operational use of the Matching Familiar Figure Test. In terms of the particular quality which the Matching Familiar Figure purports to measure, the response time would on first sight seem to be the most direct measure of reflectivity-impulsivity because it may be argued that a reflective person would require longer to make a decision than an impulsive thinker. A number of researchers have indeed used response time as their main criterion measure of reflectivity-impulsivity. The same procedure has been followed in the present study.

An alternative approach to the labelling of reflectivity and impulsivity has also been used; in this both criteria (response time and error rate) are employed simultaneously. In this approach, impulsivity is characterised by low response times and high error rates, whereas reflectivity is characterised in terms of long response times and low error scores. This was done by using a two-way median split technique which is summarised in Figure 4.1.

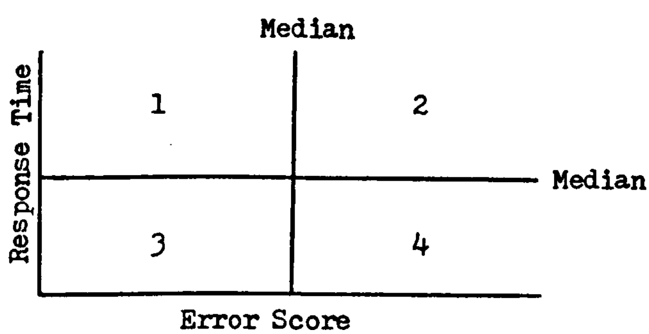

Figure 4.1 Two-way Median Split Technique

1 - Population with long answering period and low error rate (Reflective group).

2 - Population with short answering period and high error rate (Impulsive group).

3 - Population with short answering period and low error rate.

4 - Population with long answering period and high error rate.

Double classification leads to situations (group 3 and 4) where the two criteria do not reinforce each other. These are normally eliminated from consideration.

b) Correlations between reflectivity-impulsivity measures and other measures

The correlational analysis reveals no significant relationships between response time and IQ scores and between error scores and IQ scores. Likewise, no significant correlations were found to exist between the error score and any of the other cognitive styles variables. The response time measure, however, has low positive correlation with the "absent" scores on the two field dependence/independence measures (r=0.236 and 0.219, respectively). Attention has already been drawn to this in Section 4.81 of this chapter.

4.9 FACTOR ANALYSIS

In addition to the straightforward correlational analyses a factor analysis was carried out for all the cognitive style variables used in the Phase I study. Correlations relating to these variables were subjected to a principal component analysis followed by a varimax rotation using the usual criteria of ignoring factors with eigenvalue below 1.00 (Child, 1976). Altogether six factors could be identified, accounting for 85.3 per cent of the total variance. The results of the factor analysis are shown in Table 4.4.

Of the six factors, factor 1 and factor 6 relate unambiguously to one particular test each. Factor 1 concerns the fluency and flexibility score on the convergency-divergency measure, whilst factor 6 relates to

TABLE 4.4 VARIMAX ROTATED FACTOR MATRIX
PHASE I STUDY COGNITIVE STYLE VARIABLES (N = 143)

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Concealed Shapes Test						
Present items	0.066	0.067	0.054	-0.051	0.047	0.554
Absent items	-0.132	-0.022	0.101	0.022	0.036	0.723
Object Sorting Test						
Inferential	-0.043	0.057	-0.858	0.466	0.122	-0.053
Descriptive	0.008	-0.068	0.049	-0.971	-0.032	0.100
Relational	0.033	0.032	0.853	0.470	-0.073	-0.030
Conceptual Preference Test						
Inferential	-0.069	0.958	0.021	0.097	-0.233	0.042
Descriptive	0.046	-0.120	-0.103	-0.031	0.967	0.082
Relational	0.024	-0.756	0.074	0.055	-0.639	-0.102
Convergency-Divergency						
Fluency	0.860	-0.001	0.000	-0.057	-0.019	-0.117
Flexibility	0.887	-0.068	0.057	-0.009	0.060	0.046
Conceptual Differentiation	-0.138	0.066	0.101	0.205	-0.115	0.148

the Concealed Shapes Test which is the measure of the field independence/ field dependence cognitive style. The remaining four factors divide evenly between two tests.

Factor 3 and factor 4 between them bring together variables derived from the Object Sorting Test. These variables are the students' preference for the inferential, descriptive and relational form of sorting. What is evident from factor 3 is, that the inferential and the relational mode of sorting objects are diametrically opposed to each other. This is essentially a confirmation of the finding in the correlational matrix, which also indicates that high preference for inferential thinking style is accompanied by a low preference for relational style. The descriptive mode is represented on factor 4 and as is seen appears largely, though not entirely independent of students' leaning towards the inferential/ relational mode. Therefore, on the basis of the results from the Objects Sorting Test, we can argue that the descriptive mode is essentially independent of the other two modes (inferential and relational) which in turn are opposites.

Factor 2 and factor 5 produce a near-identical pattern but this time in relation to the Conceptual Preference Test. This, it will be remembered, is a test in which triads of objects were presented and the student was asked to select from given responses those close to his feelings. The noteworthy feature about the evaluation of the Conceptual Preference Test is, that it gives rise to ipsative rather than normative data which has already been mentioned elsewhere, will not allow correlational analysis to be conducted in the strictest possible sense. Nevertheless, the fact that the Conceptual Preference Test leads to a pattern pretty well identical to that observed for the normative Object Sorting Test is encouraging. However, it is to be noted that no direct correlation between the results on the Object Sorting Test and the Conceptual Preference Test exists.

The final test is the Conceptual Differentiation measure which as is seen does not appear on any one of the factors mentioned. It must thus be considered a variable independent of the other variables mentioned and exists on its own right.

The overall conclusion which may be drawn from this brief factor analysis is that, the cognitive style variables chosen for the analysis of learning performance in so far as they relate to the present study all have their own independent validity.

CHAPTER 5 THE PHASE I STUDY

5.0 INTRODUCTION

It is generally acknowledged that cognitive styles can affect students' learning behaviour. This was previously discussed in Chapter 2. For the purpose of this present study, a deliberate choice was made that learning and instruction should be considered in terms of two different approaches, namely the discovery and the expository approach to instruction and learning.

The cognitive styles selected for the investigation in the Phase I study were:

i) Field independence-field dependence
ii) Conceptualisation styles
iii) Conceptual differentiation
iv) Convergent and divergent thinking.

In order to investigate the connection between learning behaviour in relation to the two different formats of instruction and cognitive styles orientation, five short learning tasks were used in this phase of the study: these involved

i) the unscrambling of scrambled words
ii) the decoding of coded words
iii) the completing of letter series
iv) the completing of number series
v) finding the sum of odd-numbers series

These learning tasks have already been described and their features discussed in detail in Chapter 3.

5.1 CRITERION VARIABLES

In the case of the scrambled-words and the coded-words task the subjects were given separate recall tests at the end of the learning phase. These tests gave rise to three 'learning-outcome variables' concerning, respectively

i) the "knowledge of rules," where the subjects had to recall the rules deduced (learned) in the learning phase,

ii) the "direct application of the rules" to a set of problems similar in nature to the learning tasks,

iii) the "application of inverse rules," where the subjects had to transform a rule mentally to obtain a "reverse" rule and apply the latter to a set of problems. The subjects had not experienced this type of situation in the learning phase.

The letter series, the number series and the sum of odd-number series task gave rise to only one type of post-learning variable, concerning the direct application of rules deduced (or learned) in the learning task. For these three learning tasks, the tests to determine learning outcomes were conducted at the end of the learning sequence itself.

The Table 5.1 summaries the 'learning-outcome ' variables resulting from the five learning tasks.

Of the three types of criterion variable, the 'knowledge of rules' variable is a direct measure of whether or not learning has taken place. Hence, it can be considered a good indicator of 'learning outcome'. The same can also be said about the 'application of inverse rules' variable. For a student to be able to apply an inverse rule, he would have to have gained a level of insight into the basic rules which goes beyond that needed for the mere recall of the rule. This is so because the initial rules have to be transformed into new rules.

As for the 'direct application of rules' variable, this assumes learning to have taken place but does not in itself measure directly the extent to which the basic rules have been learned. It must be acknowledged that it is possible for the problems to be solved simply by the application of the procedures used for "decoding" the original examples. In the latter case, no explicit learning of the rules would have taken place. Hence, the results relating to this type of variable should be interpreted with caution.

TABLE 5.1 LEARNING OUTCOME VARIABLES TESTED IN PHASE I STUDY

LEARNING TASK	Type of learning outcome variable tested		
	Knowledge of Rules	Direct Application of Rules	Application of Inverse Rules
i) Scrambled words	X	X	X
ii) Coded words	X	X	X
iii) Letter series		X	
iv) Number series		X	
v) Sum of Odd-Numbers series		X	

5.2 EVALUATION STRATEGY

The main concern of the present study was the examination of the influence of a range of cognitive styles on students' learning in the context of two contrasting instructional procedures, i.e. discovery-based and expository. The general statistical technique applied to the scores of learning outcomes was the analysis-of-variance technique, either in its one-way format (outcomes examined with reference to different cognitive styles groupings, for one particular instructional strategy) or in its two-way format (when examining outcomes in relation to cognitive styles groupings and the different instructional approaches).

As has previously been pointed (Chapter 2), for the field independence/ dependence style the possible effect on learning behaviour is one that concerns both the discovery and expository mode of learning. In consequence, a two-way analysis of variance was employed to examine the effect of field independence/dependence on learning both from the discovery mode and the expository mode of learning. For the other cognitive styles, no direct influence on the learning outcome from the expository mode of instruction could be hypothesised on theoretical grounds. In consequence, the effect of the cognitive styles was examined only with respect to the discovery mode of instruction.

For the purpose of the above mentioned analyses, subjects were generally divided into three groups on the basis of their cognitive styles results. The resulting subgroups were labelled "high," "intermediate" and "low" with respect to the cognitive style examined. The results of the analyses are presented and discussed in the following sections.

5.3 RESULTS AND DISCUSSIONS

5.31 Field independence/dependence and learning outcome

It was hypothesised that in learning situations requiring patterns to be recognised from an array of data and formulated in terms of rules (as in discovery learning), a field independent person should perform better than a field dependent person. However, by comparison a field dependent person might be expected to not to be at a similar disadvantage when learning from a more direct instructional approach where patterns and rules are presented, rather than having to be deduced.

To examine this hypothesis expirically, a two-way analysis of variance was performed on students' scores on the learning outcome variables. The student sample was divided into three approximately equal groups, according to the subjects' scores on the "present" items of the Concealed Shapes Test. Students scoring between 16 and 35 were assigned to the field dependent group, students scoring from 36 to 41 formed the intermediate group, and students scoring 42 and above were defined as the field independent.

The results are presented below for each of the learning tasks.

a) Scrambled Words Task

Table 5.2 gives the means and standard deviations and Table 5.3 presents the summary of the analyses of variance (ANOVA) of the learning outcome variables of the scrambled words task.

The two-way ANOVA performed on the data obtained from the three post learning tasks showed no significant interaction to exist between the levels of field independence-field dependence on the one hand and modes of instruction used on the other, at least as far as the first two tasks (knowledge of rules, direct application of rules) are concerned. For the third task which concerns the application of inverse rules an interaction is observed between the two main effects. This is discussed further below.

It must be remembered that in terms of the primary research task, namely, the investigation between the field independence on the one hand and learning performance on the other, the hypothesis presented above is concerned primarily with discovery learning. Therefore, we must initially look particularly at the effect of the three different levels of field

TABLE 5.2 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES (SCRAMBLED WORDS TASK).

Learning Outcome Variable	Instructional Mode	Performance Score of Subgroups Max. Score = 6			Total Popul.
		Field Independent	Intermediate	Field dependent	
Knowledge of Rules	Discovery	5.07 (1.34) N=30	5.00 (1.73) N=46	4.78 (1.64) N=40	4.94 (1.56) N=116
	Expository	5.73 (0.71) N=41	5.63 (0.66) N=41	5.07 (1.47) N=42	5.48 (1.07) N=124
	Total Popul.	5.45 (1.07) N=30	5.30 (1.37) N=87	4.93 (1.55) N=82	
Direct Application of Rules	Discovery	5.00 (1.60) N=30	4.89 (1.73) N=46	4.73 (1.85) N=40	4.87 (1.71) N=116
	Expository	5.93 (0.47) N=41	5.66 (0.86) N=41	5.07 (1.54) N=42	5.55 (1.13) N=124
	Total Popul.	5.54 (1.18) N=71	5.25 (2.09) N=87	4.90 (1.70) N=82	
Application of Inverse Rules	Discovery	4.23 (2.06) N=30	3.89 (2.09) N=46	4.00 (1.97) N=40	4.02 (2.04) N=116
	Expository	5.42 (1.10) N=41	5.05 (1.38) N=41	3.93 (2.12) N=42	4.79 (1.73) N=124
	Total Popul.	4.92 (1.67) N=71	4.44 (1.87) N=87	3.97 (2.04) N=82	

TABLE 5.3 TWO-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE AND INSTRUCTIONAL MODES (SCRAMBLED WORDS TASK).

		Learning Outcome Variables								
		Knowledge of Rules			Direct Application of Rules			Application of Inverse Rules		
Source	df	Mean Square	F-ratio	Signif. Level p≤	Mean Square	F-ratio	Signif. Level p≤	Mean Square	F-ratio	Signif. Level p≤
Field Independence/dependence	2	5.32	2.99	0.05	6.90	3.38	0.05	15.71	4.71	0.05
Instructional Modes	1	16.51	9.26	0.01	26.61	13.05	0.001	32.68	9.80	0.01
Interaction	2	0.83	0.47	N.S.	1.75	0.86	N.S	10.32	3.09	0.05
Residual	234	1.78			2.04			3.34		

independence - field dependence on achievements resulting from the discovery mode. It is seen that for the first two tasks (knowledge of rules and direct application of rules), field independent persons perform better than field dependent persons. The differences are relatively small in either case but the trend is entirely unambiguous. The fact that the differences are small is likely to be the result of the learning tasks being relatively easy, which is demonstrated by a mean achievement for all groups of students in excess of 80% of the maximum scores possible. This finding is essential in accordance with the prediction of the influence of field independence - field dependence on learning. The higher the leaning of students towards field independence, the better is their learning performance from the discovery mode.

Interestingly enough this also extends to the expository mode, certainly in relation to first two tasks. What is to be noted here, is that the overall performance level reached on the expository mode when compared with that for the discovery mode, is invariably higher. Although in the context of this study this is a finding of secondary importance, it suggests that the expository teaching mode tends to be more successful in teaching than the discovery learning method. This result however need not raise undue concern. It is very much in keeping with findings reported extensively in the literature for studies using short term retention and the ability to apply knowledge as criteria on the basis of which the relative effectiveness of discovery and expository teaching modes are assessed (Hermann 1969; Wittrock 1966).

It is important though to look at the overall effect of the field independence variable upon learning, irrespective of instructional approach used. From the first two post-learning tasks it is evident that field independent students perform better than field dependent students and this would establish field independence - field dependence as a cognitive style of significant influence upon students' learning behaviour.

The fact that this superiority bestowed by field independence, manifest itself not only in relation to discovery learning (where it would have been expected), but also in expository teaching method, must give rise to some further speculation. Two arguments present themselves:-

i) It has been shown by independent researches and by the present study also that a small but significant correlation exist between field independence scores and IQ. If IQ is indeed taken as a variable which is characteristic of mental ability and of peoples' learning capacity, then field independent students would be expected to be on average be slightly better in terms of IQ than field dependent students. They may, therefore, under any circumstances display a somewhat superior learning capacity/ability than field dependent persons. This offers one possible explanation for the observed effect.

ii) It may be argued that even if rules are presented to students in the expository procedure, students with a higher capacity for analytical thinking may be expected to do better, in that they are better suited and able to abstract and "internalise" such rules and subsequently to apply them. If this argument is accepted, it would offer an alternative explanation for the observed superiority of the field independent students: after all, one of the qualities of field independence persons is their ability to think in more analytical term than the field dependent person.

Whichever the correct explanation of the present findings may be, the data obtained in this particular experiment are insufficient to shed further light on the matter. The reason for this is that only for a relative small proportion of the examined population was it possible to obtain IQ data, and that the existing data could not be treated to partial out any IQ effect. However this particular issue of the possible interaction of field independence with IQ and the effect of this on learning will be referred to in the Phase II study which is reported in Chapter 6.

We may now turn to the third task examined in this context; the 'application of inverse rules'. An important point to be made here is that this particular task, unlike the first two, does not represent a straightforward recall task in the sense that it required students to perform exercises already previously experienced as part of the learning itself. Rather, this application task requires students to have transformed mentally the rules originally learned into the inverse rules. This is thus essentially a task which involves the mental transformation of something already learned into a new kind of concept or rule.

The data obtained for the application of inverse rules revealed two things (see Tables 5.2 and 5.3). First, with respect to the discovery mode, it is seen that all performances are very much at the same level and that any cognitive style effect is basically absent. For the expository group the situation is different. It is seen that both the field independent and intermediate subjects show a high performance level and it is only the field dependent group for whom a low performance level is observed (since the analysis of variance shows an interaction between the two main effects no analysis of this can be made as such). The results would suggest that whilst both field independent and intermediate students are able to transform the rules previously learned into a new rule (probably on account of their higher leaning towards analytical thinking), field dependent students lack this particular characteristic and so evidently have much greater difficulty and hence less success in this operation. Again, this finding confirms that field independence as a cognitive style characteristic, influences learning to a significant extent, but that this influence depends on the nature of the instructional mode used and on the type of learning task.

b) Coded Words Task

The second learning task with respect to which the influence of field independence - field dependence was examined was the Coded words task. Tables 5.4 and 5.5 present the basic data obtained and the two-way analyses of variance performed on the data for the post-learning tasks.

Distinguishing again between the first two tasks (knowledge of rules and direct application of rules) and the third task (application of inverse rules) in accordance with the argument presented in the preceding section, it is seen from the tables that for the first two variables the performance level of the field independent student is again higher than that of the field dependent students. Thus, field independence - field dependence as a main variable is found to be of significant influence on student learning behaviour. This effect is clearest for the knowledge-of-rules variable, whilst for the direct application of rules task a significance level is reached which is just about significant at the 5% level. The conclusions to be drawn from these findings are basically the same as those presented in the previous section.

It is of interest to note that the instructional modes appear to have very little, if any influence on the learning behaviour of students. It is seen that both groups of students (exposed to the discovery and expository treatments, respectively) perform at comparable levels in both tasks, and hence no superiority can be ascribed to the one or the other instructional modes. However, the performance levels achieved by the two groups in relation to the two criterion tasks, are very high indeed and this may well have prevented a clear differentiation between the two instructional modes used.

TABLE 5.4 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES (CODED WORDS TASK).

Learning Outcome Variable	Instructional Mode	Performance Score of Subgroups Max. Score = 8			Total Popul.
		Field Independent	Intermediate	Field Dependent	
Knowledge of Rules	Discovery	7.13 (1.77) N=54	6.03 (2.29) N=34	6.13 (2.19) N=31	6.56 (2.16) N=119
	Expository	6.83 (2.04) N=24	7.02 (1.89) N=41	5.80 (2.72) N=25	6.63 (2.23) N=90
	Total Popul.	7.04 (1.85) N=78	6.57 (2.13) N=75	5.98 (2.42) N=56	
Direct Application of Rules	Discovery	7.02 (1.31) N=54	6.56 (1.91) N=34	6.71 (1.99) N=31	6.80 (1.76) N=119
	Expository	7.38 (1.17) N=24	6.63 (1.32) N=41	6.36 (1.87) N=25	6.75 (1.47) N=90
	Total Popul.	7.13 (1.27) N=78	6.60 (1.60) N=75	6.55 (1.93) N=56	
Application of Inverse Rules	Discovery	3.61 (3.22) N=54	2.38 (2.52) N=34	2.71 (2.75) N=31	3.02 (2.94) N=119
	Expository	2.83 (3.03) N=24	2.29 (2.65) N=41	2.96 (2.99) N=25	2.62 (2.86) N=90
	Total Popul.	3.37 (3.17) N=78	2.23 (2.58) N=75	2.82 (2.84) N=56	

TABLE 5.5 TWO-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE AND INSTRUCTIONAL MODES (CODED WORDS TASK).

		Learning Outcome Variables								
		Knowledge of Rules			Direct Application of Rules			Application of Inverse Rules		
Source	df	Mean Square	F-ratio	Signif. Level p≤	Mean Square	F-ratio	Signif. Level p≤	Mean Square	F-ratio	Signif. Level p≤
Field Independence/dependence	2	18.87	4.26	0.05	7.37	2.91	0.057	17.75	2.13	N.S
Instructional Modes	1	1.66	0.37	N.S	0.13	0.05	N.S	2.52	0.30	N.S
Interaction		9.85	2.23	N.S	1.89	0.75	N.S	4.27	0.60	N.S
Residual	203	4.43			2.54			8.35		

As far as the third criterion task (application of inverse rules) is concerned, the general performance level is on the low side suggesting their neither group of students found this particular set of task easy. The analysis of variance produced an F-ratio for the field independence effect of 2.13. This value fails to reach an acceptable statistical significance level. Therefore, no discussion can be offered about the scores obtained for the application of inverse rules task.

c) <u>Letter Series and Number Series Tasks</u>

For these learning tasks only one type of post-learning variable was examined, viz. the direct application of rules deduced in the learning tasks. The relevant data are presented in Tables 5.6 and 5.7.

Neither learning task offers much support for the hypothesis that field independent students perform significantly better than field dependent students do. On close analysis of the mean scores obtained for the discovery groups, it is recognised that the two extreme cognitive styles groups behave in the way that could have been expected from the finding in relation to the previous two tasks, but the results for the intermediate group upset this pattern. The intermediate group, in fact, shows score levels which are equal, or marginally above those obtained by field independent persons and field dependent persons respectively. No explanation can be given for this since no ancillary data are available on the basis of which the relative difference between the three cognitive style groups might have been examined. However, when taking the field independent and intermediate groups together, their performance level is distinctly higher than that of the field dependent group.

In the case of either task, the instructional mode by means of which learning took place appears as a variable of major importance. In each case, the expository procedure leads to higher achievement than the

TABLE 5.6 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES (LETTER AND NUMBER SERIES TASKS.

Learning Outcome Variable	Instructional Mode	Performance Score of Subgroups Max. Score = 12			Total Popul.
		Field independent	Intermediate	Field Dependent	
Direct Application of Rules (Letter Series)	Discovery	10.63 (1.83) N=30	10.93 (1.55) N=30	10.07 (2.41) N=29	10.52 (1.97) N=89
	Expository	11.71 (0.78) N=21	11.06 (1.72) N=32	10.75 (2.29) N=24	11.14 (1.76) N=77
	Total Popul.	11.08 (1.57) N=51	11.00 (1.63) N=62	10.37 (2.36) N=53	
Direct Application of Rules (Number Series)	Discovery	9.80 (2.67) N=30	10.27 (2.48) N=30	9.10 (2.26) N=29	9.73 (2.61) N=89
	Expository	11.33 (1.39) N=21	11.38 (1.74) N=32	10.92 (1.98) N=24	11.22 (1.72) N=77
	Total Popul.	10.43 (2.34) N=51	10.84 (2.18) N=62	9.93 (2.50) N=53	

TABLE 5.7 TWO-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE AND INSTRUCTIONAL MODES (LETTER AND NUMBER SERIES TASKS).

		Learning Outcome Variable					
		Direct Application of Rules (Letter Series)			Direct Application of Rules (Number Series)		
Source	df	Mean Square	F-ratio	Signif. Level p<	Mean Square	F-ratio	Signif. Level p<
Field Independence/ dependence	2	8.77	2.53	N.S	9.90	1.98	N.S
Instructional Modes	1	15.50	4.47	0.05	87.62	17.54	0.01
Interaction	2	3.29	0.95	N.S	1.81	0.36	N.S
Residual	160	3.34			4.61		

discovery mode, irrespective of cognitive style leaning. This is entirely in line with the observation made with the first learning task in which a general superiority of the expository teaching approach over the discovery approach was established, for the short term exercises. It must be borne in mind that the post-test in the case of these present two learning tasks were conducted at the end of the learning sequence itself. This meant that student learning by the expository procedure had at their disposal an overt statement of the rules to be learned as the result of the learning task. It may well be that the advantage gained from the availability of the statement of rules manifested itself in the higher scores levels shown by the Expository Group.

d) <u>Sum of Odd-Numbers Series Task</u>

Data obtained for this task are presented in Tables 5.8 and 5.9. The analysis of variance data (table 5.9) reveals that there is a significant interaction between the two independent variables examined, i.e. the cognitive style and instructional mode. Therefore, no summary pronouncement can be made about their respective influence. In relation to the students following the discovery procedure, the relevant data in Table 5.8 offer considerable support for the notion that field-independence influences learning to a significant extent: as is seen, the mean score for the field independent group is very much higher than the mean score for the other two groups. In contract, the results for the expository instructional mode does not reveal any major significant difference to exist between the performance of the three cognitive style groups.

In the overall sense, subjects following the discovery mode found this particular task rather more difficult than the other learning tasks. This may be responsible for bringing about better discrimination between field dependent and field independent subjects than was previously

TABLE 5.8 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLE (SUM OF ODD-NUMBERS SERIES TASK).

Learning Outcome Variable	Instructional Modes	Performance score of Subgroups Max. Score=8			Total Popul.
		Field Independence	Intermediate	Field dependence	
Direct Application of Rules	Discovery	6.88 (1.76) N=25	4.71 (3.18) N=45	4.71 (3.18) N=34	5.23 (3.04) N=104
	Expository	6.47 (2.51) N=47	6.62 (1.59) N=29	6.16 (1.52) N=25	6.43 (2.05) N=101
	Total Popul.	6.61 (2.27) N=72	5.46 (2.86) N=74	5.32 (2.69) N=59	

TABLE 5.9 TWO-WAY ANALYSIS OF VARIANCE OF LEARNING OUTCOME VARIABLE WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE AND INSTRUCTIONAL MODES (SUM OF ODD-NUMBERS SERIES TASK.

	Learning Outcome Variable			
	Direct Application of Rules			
Source	df	Mean Square	F-ratio	Signif. level $p\leq$
Field Indepencence/ Dependence	2	21.19	3.32	0.05
Instructional Modes	1	47.45	7.44	0.01
Interaction	2	25.05	3.93	0.05
Residual	199	6.38		

established. The result points firmly in one direction: that field independent learners have significant advantages in situations which required data to be analysed and translated into appropriate patterns, without external cuing.

Conclusion

On the whole, the results obtained in this part of the study support the hypothesis that field independence, as a major cognitive style characteristic, has a significant influence on learning. Especially in discovery learning situations, field independent persons enjoy a significant advantage, for reasons discussed above. However, the issue of the relationship between field independence and IQ has to be resolved before a final pronouncement about this can be made. As stated earlier, this issue is examined in the Phase II (chemistry learning) study which is reported in the next chapter.

A finding of secondary importance in the context of the present study, is that the expository teaching method is found to be generally more successful in teaching the concepts than the discovery learning method, if success is measured in terms of immediate learning. This result, is very much in keeping with findings reported extensively in the literature for studies using short-term retention as a criterion of learning. Having established this in this part of the study, we need not examine this issue further in the following analyses of the influence of other cognitive styles on learning.

5.32 CONCEPTUALISATION STYLES AND LEARNING BEHAVIOUR

As pointed out in Chapter 2 (section 2.62), the influence of conceptualisation styles is likely to manifest itself in connection with discovery learning rather than expository learning. It was hypothesised that, of the three conceptualisation styles, the inferential style should have a direct bearing on students' success in discovery learning in the sense that the higher an individual's learning towards inferential thinking, the better should be his performance in discovery learning. The reason for this is that the inferential style appears to involve an analytic as well as a synthetic thinking component both of which are essential for success in discovery learning. To a lesser extent the same could also apply to descriptive conceptualisation style, since the descriptive style reflects a tendency to analyse the parts of stimuli presented, but without the synthesis element. The relational style which is concerned mainly with contextual relationship between whole stimuli, is thought not to have any direct influence on discovery learning.

In the following analysis and discussion of data, particular attention is therefore given to the relationship between the inferential conceptualisation style and the students' success in the learning tasks involving the discovery procedure, although the effects of the other two conceptualisation modes are also considered.

Since there are three conceptualisation styles considered in this part of the study, the results are presented and discussed under three separate subheadings dealing, respectively, with the inferential style, descriptive style and the relational style. In each subsection, an analysis of the post-learning variables is presented. A general summary of the findings is presented at the end of the three subsections.

Subsection A: Inferential Conceptualisation Style

Students' scores on the post-learning variables were analysed, using the one-way analysis of variance procedure for each instructional unit. Subjects were divided into three groups (of approximately equal population), according to their scores on the inferential style part of the Conceptual Preference Test. In practice, this meant that students scoring between 41 and 57 were allocated to the 'low' inferential group, subjects scoring between 58 to 64 were defined as 'intermediate' and subjects scoring 65 and above were allocated to the 'high' inferential group. Table 5.10 gives the means and standard deviations achieved by these three groups on the various post-learning variables. The variables as such are identified in the table. Table 5.11 summarises the results of the one-way analyses of variance on these data.

It is seen that in both situations where students were required to learn and recall rules (scrambled words task and coded words task), a statistically significant variation of scores with levels of inferential thinking is observed. Qualitatively, it is seen that the higher the students' leaning towards the inferential thinking mode, the higher is their mean score on the knowledge of the rules. This finding is in full agreement with the hypothesis advanced earlier, namely, that students with a high tendency towards the inferential thinking mode should perform better than other students as far as the learning of rules by the discovery procedure is concerned. It may be concluded therefore, that the tendency towards high inferential thinking in students promoted their success in learning tasks which require the abstraction of information from stimuli and the subsequent synthesis of such information into patterns.

This view is also confirmed by the superior performance of high inferential thinkers on the two sets of tasks requiring the application of the inverse rules. As has previously been pointed out, the application of inverse rules requires students to have gained a level of insight, beyond that required for the mere discovery of the basic rules. It may, in fact, be argued that the inverse application of the original rules presupposes the discovery of a further set of rules from the original ones. In this case, in relation to students of high inferential thinking style, a similar advantage would be expected as in the original discovery task leading to the formulation of the basic rules.

TABLE 5.10 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES FROM ALL TASKS WITH RESPECT TO LEVELS OF INFERENTIAL CONCEPTUALISATION.

Learning Outcome Variable	Task (Max. Score)	Peformance Score of Subgroups		
		High Inferential	Intermediate	Low Inferential
Knowledge of Rules	Scrambled Words (Max. Score=6)	5.66 (0.64) N=35	5.17 (1.32) N=30	4.25 (2.11) N=24
	Coded Words (Max. Score=8)	7.19 (1.83) N=26	6.56 (1.94) N=25	5.74 (2.21) N=27
Direct Application of Rules	Scrambled Words (Max. Score=6)	5.34 (1.16) N=35	5.13 (1.56) N=30	4.46 (2.21) N=24
	Coded Words (Max. Score=8)	7.27 (1.22) N=26	6.68 (1.46) N=25	6.81 (1.80) N=27
	Letter Series (Max. Score=12)	11.04 (1.40) N=25	10.73 (1.78) N=30	10.55 (1.92) N=11
	Number Series (Max. Score=12)	10.28 (2.17) N=25	9.47 (2.73) N=30	10.73 (2.00) N=11
	Sum of Odd-Numbers Series (Max. Score=8)	6.00 (2.21) N=21	4.31 (3.52) N=29	6.25 (1.88) N=32
Application of Inverse Rules	Scrambled Words (Max. Score=6)	4.71 (1.72) N=35	4.00 (2.02) N=30	3.46 (2.19) N=24
	Coded Words (Max. Score=8)	4.54 (3.05) N=26	2.28 (2.26) N=25	2.78 (2.66) N=27

TABLE 5.11 SUMMARY OF ONE-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF INFERENTIAL CONCEPTUALISATION.

Variable	Task	df	Mean Squares		F-ratio	Signif. Level p≤
			Between	Within		
Knowledge of Rules	Scrambles Words	2/86	14.16	1.94	7.31	0.01
	Coded Words	2/75	14.05	4.02	3.50	0.05
Direct Application of Rules	Scrambled Words	2/86	5.79	2.67	2.17	N.S
	Coded Words	2/75	2.45	2.30	1.07	N.S
	Letter Series	2/63	1.13	2.79	0.41	N.S
	Number Series	2/63	8.15	5.85	1.39	N.S
	Sum of Odd-Numbers Series	2/79	32.15	7.02	4.58	0.01
Application of Inverse Rules	Scrambled Words	2/86	11.64	3.82	3.04	0.05
	Coded Words	2/75	36.27	7.76	4.67	0.01

This is borne out by the present result. It is seen that the higher the leaning towards inferential thinking, the greater is the performance level of the three groups of the students on the task requiring the application of the inverse rules.

As far as the direct application of the rules variables are concerned, no significant difference appears in the performance level of the groups having different levels of inferential thinking, except in the case of the sum of odd-numbers series task. The difference here is due to the peculiar performance of the middle group, rather than to a systematic variation. The general absence of any systematic and significant difference between the groups may be due to the fact that the tasks involved in the direct application of rules can be solved simply by applying the procedure used for decoding the original examples. If this is so, the differential leaning of individuals towards inferential thinking cannot be expected to have any direct influence on this achievement here.

Subsection B: Descriptive Conceptualisation Style

For the purpose of the analysis, the subjects were divided into three groups according to their scores on the descriptive style part of the Conceptual Preference Test. Students scoring between 26 and 36 were grouped as 'low' descriptive, those scoring from 37 to 42 were defined as 'intermediate' and those scoring 43 and above were defined as 'high' descriptive. Table 5.12 gives the means and standard deviations achieved by the three groups on the post-learning variables, and Table 5.13 presents a summary of the one-way analyses of these data.

It is seen from Table 5.12 that the performance on the 'knowledge of rules' variables does not show any major variation across the groups. This is confirmed by the analysis of variance which fails to reveal any significant differences between the groups. The same is true for the

TABLE 5.12 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES FROM ALL TASKS WITH RESPECT TO LEVELS OF DESCRIPTIVE CONCEPTUALISATION.

Learning Outcome Variable	Task (Max. Score)	Performance Score of Subgroups		
		High Descriptive	Intermediate	Low Descriptive
Knowledge of Rules	Scrambled Words (Max. Score=6)	5.07 (1.66) N=30	5.36 (1.08) N=25	4.97 (1.60) N=34
	Coded Words (Max. Score=8)	6.34 (2.17) N=35	6.68 (1.99) N=25	6.50 (2.07) N=18
Direct Application of Rules	Scrambled Words (Max. Score=6)	5.07 (1.93) N=30	5.40 (1.08) N=25	4.74 (1.73) N=34
	Coded Words (Max. Score=8)	6.86 (1.78) N=35	7.28 (1.02) N=25	6.56 (1.50) N=18
	Letter Series (Max. Score=12)	10.70 (1.82) N=23	10.64 (1.63) N=25	11.22 (1.48) N=18
	Number Series (Max. Score=12)	10.26 (2.09) N=23	10.16 (2.84) N=25	9.25 (2.25) N=18
	Sum of Odd-Numbers Series (Max. Score=8)	6.72 (1.03) N=29	5.22 (2.92) N=23	4.53 (3.36) N=30
Application of Inverse Rules	Scrambled Words (Max. Score=6)	3.70 (2.28) N=30	4.48 (1.73) N=25	4.26 (1.91) N=34
	Coded Words (Max. Score=8)	3.14 (2.86) N=35	3.64 (2.80) N=25	2.72 (3.25) N=18

TABLE 5.13 SUMMARY OF ONE-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF DESCRIPTIVE CONCEPTUALISATION.

Variable	Task	df	Mean Squares		F-ratio	Signif. Level p≤
			Between	Within		
Knowledge of Rules	Scrambled Words	2/86	1.14	2.24	0.51	N.S
	Coded Words	2/75	0.83	4.37	0.19	N.S
Direct Application of Rules	Scrambled Words	2/86	3.21	2.73	1.18	N.S
	Coded Words	2/75	2.88	2.29	1.26	N.S
	Letter Series	2/63	2.04	2.76	0.74	N.S
	Number Series	2/63	4.46	5.97	0.75	N.S
	Sum of Odd-Numbers Series	2/79	36.66	6.90	5.31	0.01
Application of Inverse Rules	Scrambled Words	2/86	4.61	3.99	1.56	N.S
	Coded Words	2/75	4.53	8.61	0.53	N.S

'direct application of rules' variables, where no significant influence of this style is observed in relation to students' performance on the verbal tasks (scrambled words, coded words and letter series). However, some such influence appears in the numerical tasks (number series and sum of odd-number series) where a higher leaning towards the descriptive conceptualisation style is accompanied by a higher performance on the relevant variables. However, the analyses of variance data reveal this trend to be significant only in the case of the sum of odd-numbers task.

The strong effect of descriptive style on the sum of odd-numbers rule may be explained in terms of the nature of this task. Unlike the other tasks in the study, this task requires the students to analyse a set of information and abstract a relationship between the information provided. There was no 'decoding of exemplars' involved as in the other tasks. Also, the explicit knowledge of the rule is a prerequisite for success in further tasks. It appears that the analysis component of the descriptive style thinking has a significant influence on such learning situation.

As for the application of inverse rules variable, no clear trend appears in the performance level of the groups and also no significant difference is observed between the groups.

In general, it can be said that the hypothesised (mild) influence of the preference for descriptive conceptualisation style, (which is that a high leaning towards the descriptive style would be associated by a somewhat higher performance level on the post-learning tasks) is absent in the verbal tasks, but appears to some extent in the numerical tasks.

Subsection C. Relational Conceptualisation Style

For the analysis of the effect of the relational style, the same procedure was used as for the other two conceptualisation styles. The subjects were divided into three groups according to their scores in the relational style part of the Conceptual Preference Test. Students scoring between 28 and 40 were allocated to the 'low' relational group, students scoring from 41 to 46 were defined as 'intermediate' and students scoring 47 and above were defined as 'high' relational. Table 5.14 gives the means and standard deviations achieved by these groups. Table 5.15 summarises the one-way analyses of variance on the data.

The performance level in the "knowledge of rules" variables generally indicate an inverse relationship with relational thinking style, i.e., the lower the preference for relational style the higher the learning outcome. In the case of the scrambled words task, this trend is statistically highly significant ($p<0.01$). This finding would seem to be in conflict with the theoretical argument advanced above, according to which no association was expected between levels of relational thinking and performance on discovery learning tasks. On theoretical grounds, there is no obvious reason why the original argument should be abandoned and, therefore, explanations for the observed trend have to be looked for in other directions. Two possible explanations present themselves, in fact. The first arises from the ipsative nature of the conceptual preference data. As the correlational analysis in Chapter 4 revealed, a strong inverse relationship was found between relational and inferential scores on the conceptual preference test. The r-value calculated using the usual normative procedure, was - 0.62; (for an 'unbiased' ipsative test with three variables, a value of - 0.5 would be expected). Thus, in terms of score values as such, a low relational score is equivalent to a high inferential score, and vice versa. This, it must be stressed is a consequence of the ipsative nature of the conceptual preference data, and no psychological significance can be attributed to it. Nevertheless, it does have the effect of producing artificially the inverse association of levels of relational thinking

TABLE 5.14 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES FROM ALL TASKS WITH RESPECT TO LEVELS OF RELATIONAL CONCEPTUALISATION.

Learning Outcome Variables	Task (Max. Score)	Performance Score of Subgroups		
		High Relational	Intermediate	Low Relational
Knowledge of Rules	Scrambled Words (Max. Score=6)	4.59 (1.89) N=34	5.11 (1.34) N=28	5.78 (0.51) N=27
	Coded Words (Max. Score=8)	6.30 (1.96) N=23	6.04 (2.32) N=23	6.94 (1.92) N=32
Direct Application of Rules	Scrambled Words (Max. Score=6)	4.68 (1.98) N=34	4.93 (1.61) N=28	5.59 (1.05) N=27
	Coded Words (Max. Score=8)	6.78 (1.41) N=23	6.87 (1.52) N=23	7.06 (1.62) N=32
	Letter Series (Max. Score=12)	10.63 (1.92) N=19	10.80 (1.57) N=15	10.94 (1.56) N=32
	Number Series (Max. Score=12)	10.00 (2.21) N=19	9.60 (3.20) N=15	10.16 (2.20) N=32
	Sum of Odd-Numbers Series (Max. Score=8)	5.11 (3.04) N=37	5.58 (2.94) N=26	6.16 (1.74) N=19
Application of Inverse Rules	Scrambled Words (Max. Score=6)	4.03 (2.14) N=34	3.93 (1.82) N=28	4.48 (2.03) N=27
	Coded Words (Max. Score=8)	2.78 (2.99) N=23	2.74 (2.72) N=23	3.84 (2.96) N=32

TABLE 5.15 SUMMARY OF ONE-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF RELATIONAL CONCEPTUALISATION.

Variable	Task	df	Mean Squares		F-ratio	Signif. Level p≤
			Between	Within		
Knowledge of Rules	Scrambled Words	2/86	10.65	2.02	5.28	0.01
	Coded Words	2/75	5.89	4.34	1.39	N.S
Direct Application of Rules	Scrambled Words	2/86	6.54	2.65	2.47	N.S
	Coded Words	2/75	0.57	2.35	0.24	N.S
	Letter Series	2/63	0.56	2.80	0.20	N.S
	Number Series	2/63	1.58	6.06	0.26	N.S
	Sum of Odd-Numbers Series	2/79	7.03	7.65	0.92	N.S
Application of Inverse Rules	Scrambled Words	2/86	2.41	4.04	0.60	N.S
	Coded Words	2/75	11.08	8.43	1.31	N.S

with 'learning-of-rules' scores.

The other possible explanation stems from the fact that of the three conceptualisation style variables, only the relational preference scores correlate negatively with IQ ($r = -0.32$, $p<0.05$). If it is assumed that an IQ - influence exists on learning performance as such, the group with the low 'relational' classification would be expected to perform better than that with the high classification. This is indeed the case and, although the present argument is speculative in nature, it may well represent an acceptable explanation.

The inverse relationship noted in the foregoing is maintained in the direct application of rules and in the application of inverse rules variables but the difference in the performance levels of the groups are not large enough to show statistical significant difference between the groups. This may be due to the generally high performance level of all the groups in the direct application of rules variables and the low and varied performance of the members of all the groups in the application of inverse rules. This phenomenon could have masked any difference that might have existed in reality.

Conclusion

In general, the results are in agreement with the initial hypothesis that the inferential conceptualisation style has a significant influence on concept attainment in discovery learning. But the initial hypothesis that the descriptive conceptualisation style too might have a moderate influence on discovery learning was not generally borne out by the results. It appears only to a moderate extent with the numerical tasks. In the case of the relational conceptualisation style no direct relationship to learning outcomes was envisaged. The result is in support of this. However, a moderate general inverse relationship is observed. If low relational score is taken as indicative of a positive preference for a more analytical style, the results bear support to the initial hypotheses, i.e., leaning towards analysis - synthesis thinking has a significant influence on concept attainment via the discovery procedure.

5.33 Conceptual Differentiation and Learning Behaviour

Close examination of conceptual differentiation trait reported in Chapter 2, section 2.63, revealed conceptual differentiation to be a complex style. However, it was hypothesised that if there is to be any relationship between learning and an individual's degree of conceptual differentiation, a low differentiator (because of his analytic-synthetic character) might have some advantage over an individual having a leaning towards high differentiation, in concept attainment tasks to be accomplished by means of a discovery learning mode.

To examine this hypothesis, the subjects were divided into three groups according to their scores on the Object Sorting Test. Subjects scoring between 2 and 12 comprised the 'low' differentiators, subjects scoring between 13 and 16 were defined as 'intermediate' and subjects scoring 17 and above were defined as 'high' differentiators. Table 5.16 gives the means and standard deviations achieved by these three groups on the various post-learning tasks for the five instructional units. Table 5.17 summarises the results of the one-way analyses of variance on these data.

In the first set of variables (knowledge of rules), the high differentiation group performed marginally better than the low group, but the analysis of variance showed the differences between the groups not to be statistically significant. In the direct application of rules variables no clear trend emerges and there is very little difference between the performance levels of the groups. In the third set of

TABLE 5.16 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES FROM ALL TASKS WITH RESPECT TO LEVELS OF CONCEPTUAL DIFFERENTIATION.

Learning Outcome Variable	Task (Max. Score)	Performance Score of Subgroups		
		High Differentiation	Intermediate	Low Differentiation
Knowledge of Rules	Scrambled Words (Max. Score=6)	5.41 (1.24) N=37	4.65 (1.72) N=26	4.95 (1.54) N=39
	Coded Words (Max. Score=8)	6.51 (1.65) N=35	6.16 (2.35) N=31	6.19 (2.67) N=26
Direct Application of Rules	Scrambled Words (Max. Score=6)	5.24 (1.54) N=37	4.39 (1.75) N=26	5.08 (1.58) N=39
	Coded Words (Max. Score=8)	6.83 (1.34) N=35	6.94 (1.63) N=31	6.23 (2.50) N=26
	Letter Series (Max. Score=12)	10.39 (1.83) N=28	11.29 (1.24) N=28	10.69 (2.02) N=16
	Number Series (Max. Score=12)	10.04 (2.34) N=28	9.93 (2.69) N=28	9.88 (2.53) N=16
	Sum of Odd-Numbers Series (Max. Score=8)	5.63 (2.77) N=35	4.79 (2.92) N=24	6.05 (2.67) N=21
Application of Inverse Rules	Scrambled Words (Max. Score=6)	4.60 (1.79) N=37	4.04 (1.87) N=26	3.69 (2.17) N=39
	Coded Words (Max. Score=8)	3.23 (3.15) N=35	3.50 (3.25) N=31	2.91 (3.00) N=26

TABLE 5.17 SUMMARY OF ONE-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF CONCEPTUAL DIFFERENTIATION.

Variable	Task	df	Mean Squares		F-ratio	Signif. Level p≤
			Between	Within		
Knowledge of Rules	Scrambled Words	2/99	4.57	2.21	2.07	N.S
	Coded Words	2/89	1.25	4.91	0.25	N.S
Direct Application of Rules	Scrambled Words	2/99	6.05	2.58	2.34	N.S
	Coded Words	2/89	4.01	3.34	1.20	N.S
	Letter Series	2/69	5.72	2.81	2.04	N.S
	Number Series	2/69	0.15	6.53	0.02	N.S
	Sum of Odd-Numbers Series	2/77	9.45	7.78	1.22	N.S
Application of Inverse Rules	Scrambled Words	2/99	7.81	3.84	2.03	N.S
	Coded Words	2/89	2.83	8.42	0.34	N.S

variables, i.e., the application of inverse rules, the high differentiation group again did marginally better than the low differentiation group, but again this was not found to be statistically significant.

Conclusion

The results of the analyses do not establish any clear influence of students' conceptual differentiation behaviour on their learning behaviour, at least with the present set of tasks. Conceptual differentiation seems mainly concerned with the degree of dividing sets of stimuli into different number of subsets. In subdividing a set of stimuli some individuals may look for differences between the stimuli and thus peoduce a large number of subgroups, whilst others may look for similarities among stimuli to form few superordinate groups. This cognitive differentiation appears not significant to produce differences in learning outcome via the discovery mode of learning. On the basis of the present study, it appears that conceptual differentiation does not have a direct influence on learning behaviour associated with concept formulation. It may be, of course, that the learning tasks utilised in the present study do not have the basic characteristics which maximise the differentiation between high and low conceptual differentiators, but this can only be resolved by a further study of the problem.

5.34 Convergency-divergency and Learning behaviour

With respect to this cognitive style it was hypothesised (Chapter 2, section 2.64) that convergent thinkers (because of the inner trait to look for a solution that satisfies all instances) should have higher success rate in finding the correct or acceptable solution in discovery learning situations, compared with the divergent thinkers who would tend to look for a range of possible solutions but, in doing so, may not examine their "solutions" sufficiently critically for correctness or acceptability. This tendency can of course, manifest itself only if a learning situation really does allow alternative solutions to be produced. In the present investigation, no attempt was made to design deliberately such learning situations, Therefore, the results must be considered tentative and exploratory.

For the purpose of this aspect of the study, the subjects were divided into three groups on the basis of their flexibility scores in the Uses of Objects Test. Subjects scoring between 8 and 17 were allocated to the 'low flexibility' group (convergent thinkers), subjects scoring between 18 and 22 were defined as "intermediates" and subjects scoring 23 and above were defined as divergent thinkers. Table 5.18 gives the means and standard deviations achieved by these three groups on the various post-learning tasks. Table 5.19 summarises the results of the analyses of variance carried out on the data in Table 5.18.

When the "knowledge of rules" scores are examined (Table 5.18), the middle group is seen to be "outside" the trend expected. But the significant difference in the performance levels of the groups in the case of the Scrambled Words Task is not solely caused by the peculiar result of the middle group; t-test applied to the mean scores of the two extreme groups (the convergers and divergers), shows the difference to be highly significant ($t=2.76$; $p<0.01$). This result supports the hypothesis that divergent thinkers would have difficulty in learning situation which required them to arrive at a unique solution that satisfies all given instances. However, this effect is not seen for the Coded Words Task; this may be due to the exceptionally high performance level of all the groups (in excess of 80 per cent of the maximum score) which may have masked any difference that exists in reality between the convergers and divergers.

Again, the middle group scores are outside the expected trend in four

TABLE 5.18 MEAN SCORES AND STANDARD DEVIATIONS ON LEARNING OUTCOME VARIABLES FROM ALL TASKS WITH RESPECT TO LEVELS OF CONVERGENCY-DIVERGENCY.

Learning Outcome Variable	Task (Max. Score)	Performance Score of Subgroups		
		Divergent	Intermediate	Convergent
Knowledge of Rules	Scrambled Words (Max. Score=6)	4.04 (2.15) N=28	5.36 (1.03) N=45	5.05 (1.45) N=44
	Coded Words (Max. Score=8)	6.76 (2.05) N=29	7.17 (1.55) N=41	6.82 (1.88) N=17
Direct Application of Rules	Scrambled Words (Max. Score=6)	4.18 (2.18) N=28	5.20 (1.29) N=45	4.93 (1.70) N=44
	Coded Words (Max. Score=8)	6.72 (1.87) N=29	7.00 (1.36) N=41	7.12 (1.50) N=17
	Letter Series (Max. Score=12)	10.15 (2.28) N=27	10.61 (1.93) N=31	10.58 (1.88) N=12
	Number Series (Max. Score=12)	10.27 (1.97) N=27	8.77 (2.80) N=31	9.92 (3.26) N=12
	Sum of Odd-Numbers (Max. Score=8)	4.37 (3.56) N=27	5.12 (3.05) N=25	4.78 (3.36) N=23
Application of Inverse Rules	Scrambled Words (Max. Score=6)	3.21 (2.28) N=28	4.11 (1.82) N=45	4.45 (1.92) N=44
	Coded Words (Max. Score=8)	3.66 (3.28) N=29	3.02 (3.04) N=41	3.41 (3.18) N=17

TABLE 5.19 SUMMARY OF ONE-WAY ANALYSES OF VARIANCE OF LEARNING OUTCOME VARIABLES WITH RESPECT TO LEVELS OF CONVERGENCY-DIVERGENCY.

Variable	Task	df	Mean Squares		F-ratio	Signif. Level p≤
			Between	Within		
Knowledge of Rules	Scrambled Words	2/114	15.56	2.29	6.79	0.01
	Coded Words	2/84	1.65	3.21	0.52	N.S
Direct Application of Rules	Scrambled Words	2/114	9.21	2.86	3.22	0.05
	Coded Words	2/84	1.01	2.47	0.41	N.S
	Letter Series	2/67	1.73	4.26	0.41	N.S
	Number Series	2/67	16.85	6.81	2.47	N.S
	Sum of Odd-Numbers Series	2/72	3.67	11.12	0.33	N.S
Application of Inverse Rules	Scrambled Words	2/114	13.43	3.91	3.43	0.05
	Coded Words	2/84	3.49	9.92	0.35	N.S

out of five "direct application of rules" scores (Table 5.18). The analyses of variance reveal a significant difference ($p<0.05$) between the groups only in one case (Scrambled Words Task). This may have been caused by the high performance level of the middle group, as a t-test performed on the mean scores of the two extreme groups shows the difference between the convergers and divergers to be non-significant. Hence, it appears that the initial hypothesis is not supported by the results for this set of variables.

In the "application of inverse rules" tasks, a significant difference in performance level of the convergent and divergent thinkers is observed in the expected direction for the Scrambled Words Task i.e., the performance level of convergent thinkers are superior to that of the divergent thinkers. This is confirmed by the result of the one-way analysis of variance (Table 5.19). This result supports the initial hypothesis that convergent-divergent thinking has a significant influence on discovery learning situations requiring unique solutions to learning tasks. However, the effect is not observed for the coded words tasks. The absence of the effect may be explained in term of the rather low performance level of all the group and high variability of the scores within the groups due to the difficult nature of the task.

Conclusion

In conclusion it may be said that a general support for the initial hypothesis relating convergent and divergent thinking to discovery learning is lacking in the results of the present investigation. But a moderate support for the hypothesis appears in the case of the Scrambled Words Task. Whether, this result is genuine or has come about by chance due to some experimental condition is difficult to decide at this point. Also, it must be remembered that the present learning tasks were not specifically designed to bring out the differences between convergent and divergent thinking styles. With specially designed learning tasks that allow alternative solutions to be produced, it may be possible that significant differences are revealed between the learning behaviour of convergent and of divergent thinkers.

5.4 SUMMARY AND CONCLUSIONS

The Phase I study examined the effect of four cognitive styles on learning outcome and learning behaviour under two different modes of instruction (discovery and expository). The influence was investigated with respect to learning outcomes from five short decoding and serial tasks.

a) In general, it was found that the expository teaching method was more successful in teaching the concepts than the discovery learning method, if success is measured in terms of immediate learning. This finding is in agreement with results reported in the literature (cf. Chapter 2).

b) When it comes to the examination of the effects of cognitive styles on learning outcome two cognitive style variables were found to have significant bearing.

i) Cognitive styles related differences in achievement were found in relation to the field independence/field dependence style and the inferential conceptualisation style. In the case of the field independence/field dependence style the field independent students performed better in both the discovery and expository situation than the field dependent students. With respect to the inferential conceptualisation style the direction of difference appears to be in line with the theoretical arguments presented.

ii) All other cognitive style variables showed no consistent significant effect on learning behaviour.

In the overall sense, it therefore appears that the field independent subjects have an advantage over the field dependent subjects in learning situations (be it discovery or expository) where they are required to analyse and synthesise information on their own. Also, with respect to conceptualisation styles it appears that learning materials designed to induce students to analyse and synthesise information so that they may learn the concepts on their own would advantage the inferential thinkers but would disadvantage students who tend to favour the descriptive or relational mode of viewing information.

The above interactions were further examined with a set of chemistry learning tasks in the Phase II study where control for IQ effect was also employed. The results are reported and discussed in the next chapter.

CHAPTER 6 THE PHASE II STUDY

6.0 INTRODUCTION

The Phase II study was designed to examine the relationship between students' cognitive styles and learning behaviour in relation to a number of chemistry learning tasks. As mentioned in Chapter 3, cognitive styles chosen for this purpose were:

i) Field independence/dependence

ii) Conceptualisation styles

iii) Conceptual differentiation

iv) Convergency-divergency

v) Reflectivity-impulsivity

In order to investigate the connection between students' cognitive styles orientations and learning behaviour in chemistry tasks, four chemistry learning units were developed. A detailed description of these learning units has already been given in Chapter 3, section 3.42.

6.1 CHOICE OF CRITERION VARIABLES

As mentioned in Chapter 3, at the end of the learning phase of each chemistry learning unit the students were given further exercises to which they applied the rules/principles learned. The performance in these post-learning exercises constituted the measure of learning outcomes from the learning units. Although the actual details of the post-learning tasks varied from unit to unit, in general they assessed the following:

i) Student's ability to apply the rules which were to be learned from the given unit, in relation to the type of situation previously encountered (e.g. "normal" compounds) and to hypothetical situations.

ii) Students' ability to solve certain extension tasks requiring the application of rules/principles from more than one learning unit (this was the case in the post-tests relating to Units 3 and 4).

The distinction between these two types of skill is important in as much as only the first can be regarded as a direct measure of the learning outcome for each unit. The reason for this is that in the second type of task, where rules had to be carried forward from previous learning units, students were given summary statements of such rules. Therefore, as in the second type of task students' learning from the learning experiences is not directly tested, the variable measured in them cannot be used to investigate the relationship between learning outcome from different modes of instruction and cognitive styles. It should be pointed out that the reason for including the extension exercises in Unit 3 and Unit 4 was to make the learning experiences educationally complete and useful to the students involved in the study. Therefore, in the subsequent analysis of the relationship between learning outcome/instructional modes and cognitive styles only the first set of variables described above was considered. Table 6.1 summaries the learning outcome variables that were used in the analyses.

A further question of interest and importance in relation to the subsequent analysis of learning outcomes and cognitive styles, was whether the analysis should be conducted for learning outcome variables individually or whether a combined score can be used in the case of Units 1 and 2. To examine this, a correlational analysis was carried out between the pairs of learning outcome variables associated with these two learning units. The results are shown in Table 6.2.

TABLE 6.1 LEARNING OUTCOME VARIABLES TESTED IN PHASE II STUDY

Chemistry Learning Unit	Learning Outcome Variable	
1	(i)	Application of the relationship learned between the combining power of an element and its group number, to derive combining powers of elements.
	(ii)	Knowledge of the change in the relationship between the combining power of an element and its group number as the group number increases
2		Application of the principle that the total combining power of the metallic component of a compound is equal to the total combining power of the non-metallic component in the balanced formula of the compound, to work out and write chemical formulae of a set of
	(i)	"normal" compounds
	(ii)	hypothetical compounds
3		Application of rule that the combining power of a radical in a compound is equal to the total combining power of the metallic component divided by the number of units of radical in the compound, to calculate combining power of radicals
4		Application of the rule that the roman numeral in the name of a transition metal compound indicates the combining power of the transition metal in the compound, to deduce the combining powers of transition metals and to write chemical names of transition metal compounds

TABLE 6.2 CORRELATION BETWEEN LEARNING OUTCOME VARIABLES (UNITS 1 AND 2)

Chemistry Learning Unit	Variable Pair	Correlation Coefficient (Signif. Level)
1	Application of rules learned/ knowledge of change in relationship between combining power and group number as group number increases	0.515 (0.001)
2	Application of rules learned to normal compounds/hypothetical compounds	0.818 (0.001)

The high correlation (r=0.818) between the Unit 2 variables indicates that the performance in one task is highly related to that in the other. Hence, scores were combined for the subsequent analysis. For Unit 1, the correlation (r=0.515) was not high enough to justify the combination of the two scores, especially in view of the difference in the nature of the two variables. Unit 1 variable (ii) is essentially an additional exercise, as previously pointed out (in Chapter 3), and thus measures more than the mere knowledge of the rules learned in the unit. Hence, the two variables were examined separately in the subsequent analyses.

6.2 EVALUATION STRATEGY

As in the Phase I study reported in Chapter 5, the concern in this part of the study was again to investigate the effect of a range of cognitive styles on students' learning behaviour. The design of this part of the investigation followed the same pattern as adopted before. For the field independence/dependence style and reflectivity-impulsivity style the possible effects on learning behaviour concern both the discovery mode and expository mode of learning. In consequence, both learning modes were considered in the context of this part of the study.

An additional aspect covered during this part of the investigation, was the separate examination of the effect of IQ on the interaction between the field independence style and learning. Attention was previously drawn (in Chapter 4) to the moderate, but significant correlation observed between field independence/dependence and IQ measures. In the Phase I study, IQ data were not available to a sufficient extent to allow a partialling out of the influence of IQ on learning behaviour.

A further facet of this examination arose from the use of two different instruments for the measurement of field independence/dependence character i.e., that described by Satterley and Telfer (previously used in the Phase I study) and that developed by Kempa and Cox at the University of Keele. The latter, compared with the first, has a lower correlation with IQ measures.

For the cognitive styles other than that of field independence/dependence and reflectivity-impulsivity, no direct influence on the learning outcome from the expository mode of instruction can be hypothesised on theoretical grounds (cf. Chapter 2). Therefore, for these styles only their effect in relation to the discovery mode of instruction was examined.

Most of the cognitive style measures used in this part of the study were obtained during the Phase I study. As stated earlier (in Chapter 3), all tests were not administered to all subjects due to lack of time. Since the Phase II study sample was a subset of the Phase I population in some instance only for a small number of the Phase II study sample the test scores were available. In such instances the sample was divided into two groups and t-test analyses were carried out to investigate the effects of cognitive styles leaning on chemistry learning.

The results are presented and discussed in the following sections separately with respect to each of the cognitive styles under investigation. For ease of communication, in each case the results are presented and discussed first in relation to variables concerning the application of rules/principles learned in a unit, and then to the additional exercise concerning Unit 1.

6.3 RESULTS AND DISCUSSIONS

6.31 Field independence/dependence (as measured by Concealed Shapes Test) and chemistry learning

To examine the relationship between field independence/field dependence and chemistry learning via the discovery and expository learning modes, first a two-way analysis of variance was performed on students' scores on the post-learning tasks. Then, a separate covariance analysis was carried out, using students' IQ as the covariate in order to partial out the influence of IQ on performance. As in the Phase I study, the sample was divided into three groups (field independent, intermediate, field dependent) according to the subject's score on the "present" items of the Concealed Shapes Test.

Part (i) Application of Rules Variables

Table 6.3 presents the mean scores and standard deviations achieved by the groups on the various application of rules tasks in the four learning units. Table 6.4(a) summarises the results of the analyses of variance (ANOVA) on the data given in table 6.3

The two-way analysis of variance performed on the scores for the application of rules variables associated with the four chemistry learning units reveal no interaction between the levels of field independence/field dependence on the one hand and the modes of instruction on the other. The main hypothesis, presented in Chapter 2, about

TABLE 6.3 MEAN SCORES AND STANDARD DEVIATIONS ON THE APPLICATION OF RULES VARIABLES (FIELD INDEPENDENCE/DEPENDENCE - CST).

Application of Rules Variable (Max. Score)	Instructional Mode	Performance Scores of Subgroups			Total Popul.
		Field Independent	Intermediate	Field Dependent	
Unit 1 (11)	Discovery	10.58 (2.26) N=24	9.55 (3.00) N=20	9.57 (2.82) N=21	9.94 (2.69) N=65
	Expository	9.94 (2.93) N=16	10.09 (2.63) N=23	10.11 (2.62) N=19	10.05 (2.67) N=58
	Total Popul.	10.33 (2.54) N=40	9.84 (2.79) N=43	9.83 (2.71) N=40	
Unit 2 (18)	Discovery	11.81 (7.26) N=16	11.13 (7.89) N=23	10.32 (8.04) N=19	11.05 (7.66) N=58
	Expository	16.08 (4.37) N=24	16.30 (3.40) N=20	12.52 (6.36) N=21	15.00 (5.09) N=65
	Total Popul.	14.38 (6.00) N=40	13.54 (6.69) N=43	11.48 (7.20) N=40	
Unit 3 (6)	Discovery	3.61 (2.55) N=23	2.35 (2.06) N=20	1.50 (2.35) N=22	2.51 (2.47) N=65
	Expository	4.53 (1.81) N=15	4.35 (2.08) N=23	3.95 (2.37) N=19	4.26 (2.09) N=57
	Total Popul.	3.97 (2.31) N=38	3.42 (2.28) N=43	2.63 (2.63) N=41	
Unit 4 (32)	Discovery	14.60 (11.78) N=15	13.39 (10.32) N=23	11.84 (9.96) N=19	13.19 (10.47) N=57
	Expository	21.04 (9.13) N=23	18.60 (9.80) N=20	11.27 (8.79) N=22	16.98 (10.02) N=65
	Total Popul.	18.50 (10.60 N=38	15.81 (10.30) N=43	11.54 (9.23) N=41	

TABLE 6.4(a) TWO-WAY ANOVA ON ACHIEVEMENT SCORES (APPLICATION OF RULES VARIABLES) WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (CST) AND INSTRUCTIONAL MODES

Variable	Source of Variance	df	Mean Square	F-ratio	Signif. Level p≤
Application of Rules Unit 1	Field Independence/dependence	2	3.49	0.48	N.S
	Instructional Modes	1	0.78	0.11	N.S
	Interaction	2	4.57	0.63	N.S
	Residual	117	7.29		
Application of Rules Unit 2	Field Independence/dependence	2	81.65	1.99	N.S
	Instructional Modes	1	462.51	11.27	0.001
	Interaction	2	23.56	0.58	N.S
	Residual	117	40.96		
Application of Rules Unit 3	Field Independence/dependence	2	21.12	4.21	0.05
	Instructional Modes	1	99.90	19.93	0.001
	Interaction	2	5.81	1.16	N.S
	Residual	117	5.02		
Application of Rules Unit 4	Field Independence/dependence	2	467.91	4.78	0.01
	Instructional Modes	1	392.17	4.01	0.05
	Interaction	2	139.16	1.42	N.S
	Residual	117	97.88		

TABLE 6.4(b) TWO-WAY ANCOVA ON ACHIEVEMENT SCORES (APPLICATION OF RULES VARIABLES) WITH RESPECT TO LEVELS OF FIELD INDEPENDENT (CST) AND INSTRUCTIONAL MODES

Variable	Source of Variance	df	Mean Square	F-ratio	Signif. Level p≤
Application of Rules Unit 1	Field Independence/dependence	2	6.97	1.03	N.S
	Instructional Modes	1	4.48	0.66	N.S
	Interaction	2	0.87	0.13	N.S
	Residual	110	6.76		
Application of Rules Unit 2	Field Independence/dependence	2	30.31	0.76	N.S
	Instructional Modes	1	387.26	9.69	0.01
	Interaction	2	33.85	0.85	N.S
	Residual	110	39.96		
Application of Rules Unit 3	Field Independence/dependence	2	19.74	3.94	0.05
	Instructional Modes	1	103.99	20.73	0.001
	Interaction	2	3.83	0.76	N.S
	Residual	112	5.01		
Application of Rules Unit 4	Field Independence/dependence	2	356.29	3.75	0.05
	Instructional Modes	1	287.79	3.03	N.S
	Interaction	2	122.21	1.29	N.S
	Residual	112	95.06		

the effect of field independence/field dependence and learning, is concerned primarily with discovery learning. Therefore, looking particularly at the effect of the three different levels of field independence/field dependence for the discovery mode (data in Table 6.3), it can be seen that in all the tasks the field independent persons have performed better than the field dependent persons. The difference is only moderate in case of Unit 1 and Unit 2 tasks but distinctly higher in the case of the Unit 3 and Unit 4 tasks. The low difference in performance in Unit 1 may well be due to the generally high performance of all the groups in the task (this is in excess of 85 per cent of the maximum score possible): because of this high performance level, any differentiation between the groups is lost. In case of Unit 2 the high variability of the scores within groups as indicated by the large standard deviation seems to have masked the difference to some extent. In general, the results support the hypothesis that the higher the leaning of students towards field independence the better are their learning performances on the discovery mode tasks.

As was noted in the Phase I study (Chapter 5), this trend also extends to the expository mode. Except in the Unit 1, the field independent students performed better than the field dependent students in the expository situations. Thus, an overall effect of field independence/field dependence on chemistry learning is found, irrespective of the instructional approach used: that field independent students invariably perform better than field dependent students. The analyses of variance indicate that this finding is statistically significant at the 5 per cent level in the case of the Unit 3 task and at the 1 per cent level in the case of the Unit 4 task.

When a similar conclusion was reached in the Phase I study, two arguments were put forward to explain this phenomenon, one in terms of the higher IQ of the field independent persons, and the other in terms of the higher capacity for analytical thinking on the part of field independent subjects. In the Phase I study, IQ scores were not available for a sufficient number of subjects to examine the IQ effect. For the present phase of the study, IQ scores were available for 119 of the 127 subjects. This allowed a separate analysis of variance with IQ as covariate (ANCOVA) to be carried out. The results are presented in Table 6.4(b). It is seen from this that the significant differences in performance between field independent and field dependent students remain even after partialling out the IQ effect (in the case of Units 3 and 4). Therefore, it may be stated with confidence that it is the higher analytical capacity of the field independent subjects that gives them an edge over the field dependent individuals in learning situations be it discovery learning or learning from expository teaching.

Part (ii) Additional Exercise - Unit 1

Table 6.5 presents the basic data of the additional exercise which formed part of Unit 1.

The results on Table 6.5 show the field independent subjects have once again performed better than the field dependent subjects, in both the discovery and expository learning situation. The analysis of variance (Table 6.6a) indicates that the difference in performance is statistically significant at the 1 per cent level. When the IQ effect is controlled the significant level falls to just below the 1 per cent level (Table 6.6b). The result further confirms that field independence/dependence as a cognitive style has in general an effect on learning outcome. However, the effect is stronger in the discovery situation than in the expository situation.

6.32 Field independence/dependence (as measured by the Hidden Figures Test) and chemistry learning

The acceptance of the Concealed Shapes Test for the present study was a

TABLE 6.5 MEAN SCORES AND STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 (FIELD INDEPENDENCE/DEPENDENCE CST).

Instructional Mode	Performance Score of Subgroups Max. Score=1			Total Popul.
	Field Independent	Intermediate	Field Dependent	
Discovery	0.88 (0.34) N=24	0.50 (0.51) N=20	0.48 (0.51) N=21	0.63 (0.49) N=65
Expository	0.81 (0.40) N=16	0.74 (0.45) N=23	0.63 (0.50) N=19	0.72 (0.45) N=58
Total Popul.	0.85 (0.36) N=40	0.63 (0.49) N=43	0.55 (0.50) N=40	

TABLE 6.6(a) TWO-WAY ANOVA ON THE ADDITIONAL EXERCISE SCORE WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (CST) AND INSTRUCTIONAL MODES.

Source of Variance	df	Mean Square	F-ratio	Signif. Level p≤
Field Independence/dependence	2	1.04	5.05	0.01
Instructional Modes	1	0.41	1.97	N.S
Interaction	2	0.24	1.17	N.S
Residual	117	0.21		

TABLE 6.6(b) TWO-WAY ANCOVA ON THE ADDITIONAL EXERCISE SCORE WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (CST) AND INSTRUCTIONAL MODES

Source of Variance	df	Mean Square	F-ratio	Signif. Level p≤
Field Independence/dependence	2	0.87	4.44	0.014
Instructional Modes	1	0.69	3.50	N.S
Interaction	2	0.25	1.27	N.S
Residual	110	0.19		

matter of deliberate choice simply because the Concealed Shapes Test had been used elsewhere and therefore its characteristics were known and in fact, could be assumed. The Hidden Figures Test (HFT) had been used at Keele previously but had not been compared with any outside measures, so both measures were thought to be usable in the present study. The advantage of the HFT test, as was noted in the correlational analysis in Chapter 4, is that it is far less IQ influenced than the Concealed Shapes Test and therefore, in the absence of an extensive covariance analysis partialling out the IQ effect, the data in Table 6.7 and Table 6.9 (mean scores and standard deviations) probably provide more direct evidence of the relationship between learning and field independence/dependence than the data in Table 6.3 and Table 6.5. A detailed look at the results now follows.

The results are presented and discussed here as in the previous section. The student sample was again divided into three groups, this time according to scores on the "present items" in the Hidden Figures Test. The scores on the test ranged from 3 to 17 (Max. 18). Students scoring between 3 and 9 were allocated to the field dependent group, students scoring 10 to 12 were defined as intermediate and students scoring 13 and above were defined as field independent.

Part (i) Application of Rules Variables

Table 6.7 reports the mean scores and standard deviations achieved by the three sub-groups on the various application of rules/principles tasks. Table 6.8(a) summarises the results of the ANOVA on the data presented in Table 6.7 and Table 6.8(b) the results of the analyses of covariance. The results, as in the case of the analyses with respect to the Concealed Shapes Test scores show that there is no interaction between field independence/dependence and the instructional modes, except in the case of Unit 3 task where the intermediate group has performed

TABLE 6.7 MEAN SCORES AND STANDARD DEVIATIONS ON THE APPLICATION OF RULES VARIABLES (FIELD INDEPENDENCE/DEPENDENCE HFT).

Application of Rules Variable (Max. Score)	Instructional Mode	Performance Score of Subgroups			Total Popul.
		Field Independent	Intermediate	Field Dependent	
Unit 1 (11)	Discovery	10.32 (1.76) N=22	9.92 (1.76) N=25	9.41 (3.08) N=17	9.92 (2.71) N=64
	Expository	10.24 (2.66) N=17	10.24 (2.59) N=21	9.82 (2.74) N=22	10.08 (2.63) N=60
	Total Popul.	10.28 (2.16) N=39	10.07 (2.88) N=46	9.64 (2.86) N=39	
Unit 2 (18)	Discovery	10.59 (7.47) N=17	12.19 (7.58) N=21	9.41 (8.21) N=22	10.72 (7.75) N=60
	Expository	17.09 (2.07) N=22	15.08 (5.29) N=25	12.00 (6.32) N=17	14.95 (5.12) N=64
	Total Popul.	14.26 (6.04) N=39	13.76 (6.53) N=46	10.54 (7.47) N=39	
Unit 3 (6)	Discovery	3.76 (2.64) N=21	1.54 (2.02) N=24	2.59 (2.35) N=17	2.58 (2.49) N=62
	Expository	4.82 (1.63) N=17	4.60 (1.90) N=20	3.22 (2.44) N=22	4.19 (2.13) N=59
	Total Popul.	4.24 (2.28) N=38	2.93 (2.48) N=44	3.00 (2.40) N=39	
Unit 4 (32)	Discovery	15.24 (10.97) N=17	12.90 (10.81) N=20	11.59 (9.51) N=22	13.08 (10.32) N=59
	Expository	20.19 (10.40) N=21	16.75 (9.02) N=24	14.88 (10.80) N=17	17.40 (10.07) N=62
	Total Popul.	17.97 (10.80) N=38	15.00 (9.95) N=44	13.03 (10.09) N=39	

TABLE 6.8(a) TWO-WAY ANOVA ON ACHIEVEMENT SCORES (APPLICATION OF RULES VARIABLES) WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (HFT) AND INSTRUCTIONAL MODES

Variable	Source of Variance	df	Mean Square	F-ratio	Signif. Level p≤
Application of Rules Unit 1	Field Independence/dependence	2	4.50	0.62	N.S
	Instructional Modes	1	1.48	0.20	N.S
	Interaction	2	0.66	0.09	N.S
	Residual	118	7.28		
Application of Rules Unit 2	Field Independence/dependence	2	119.84	2.91	N.S
	Instructional Modes	1	472.14	11.47	0.01
	Interaction	2	45.51	1.13	N.S
	Residual	118	41.17		
Application of Rules Unit 3	Field Independence/dependence	2	24.57	5.07	0.01
	Instructional Modes	1	84.76	17.47	0.001
	Interaction	2	16.49	3.40	0.05
	Residual	115	4.85		
Application of Rules Unit 4	Field Independence/dependence	2	198.10	1.91	N.S
	Instructional Modes	1	482.65	4.65	0.05
	Interaction	2	6.81	0.07	N.S
	Residual	115	103.89		

TABLE 6.8(b) TWO-WAY ANCOVA ON ACHIEVEMENT SCORES (APPLICATION OF RULES VARIABLES) WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (HFT) AND INSTRUCTIONAL MODES.

Variable	Source of Variance	df	Mean Square	F-ratio	Signif. Level p$\leq$
Application of Rules Unit 1	Field Independence/dependence	2	1.41	0.21	N.S
	Instructional Modes	1	4.04	0.59	N.S
	Interaction	2	1.68	0.24	N.S
	Residual	109	6.90		
Application of Rules Unit 2	Field Independence/dependence	2	78.76	2.01	N.S
	Instructional Modes	1	332.21	8.48	0.01
	Interaction	2	45.25	1.16	N.S
	Residual	109	39.18		
Application of Rules Unit 3	Field Independence/dependence	2	23.86	5.05	0.01
	Instructional Modes	1	96.76	20.46	0.001
	Interaction	2	17.06	3.61	0.05
	Residual	109	4.73		
Application of Rules Unit 4	Field Independence/dependence	2	85.60	0.83	N.S
	Instructional Modes	1	328.37	3.20	N.S
	Interaction	2	6.12	0.06	N.S
	Residual	109	102.67		

significantly better in the expository mode than in the discovery mode. But, once again the performance of the field independent group is, in general, superior to that of the field dependent group in both the discovery and expository treatment. However, the trend is not clear-cut in all cases (discovery mode) because the performance of the intermediate group has deviated from the expected trend in both the Unit 2 and Unit 3 tasks. In Unit 2, the intermediate group has performed better than the field independent group (mean scores: intermediate group=12.19; field independent group=10.59), but in Unit 3 the same intermediate group has performed less well than the field dependent group (mean scores: intermediate group=1.54; field dependent group=2.59). No logical explanation can be put forward for these deviations.

Although in a number of instances the data actually fail to reach statistical signficance, nevertheless the investigation of the data produces some very clear differentiation. The differentiations are particularly noticeable in some instances (Units 3 and 4 - discovery mode; Units 2,3 and 4 - expository mode), in relation to the two extreme groups. In the case of Unit 3 task the differentiation is statistically significant even after partialling out the IQ effect (Table 6.8b). Hence, on the whole, the result appears in support of the earlier findings that the field independent students have an advantage over the field dependent students in learning, especially in learning situations that require analysis of information and learning of concepts own their own.

Part (ii) Additional exercise - Unit 1

Table 6.9 presents the data for this variable, and Tables 6.10(a) and 6.10(b) the results of the variance and covariance analyses respectively. The performance in the Unit 1 additional exercise follows the same trend observed in the first set of variables discussed above. A substantial difference in performance exists between the extreme groups, in both

TABLE 6.9 MEAN SCORES AND STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 (FIELD INDEPENDENCE/DEPENDENCE HFT).

Instructional Mode	Performance Score of Subgroups Max. Score=1			Total Popul.
	Field Independent	Intermediate	Field Dependent	
Discovery	0.72 (0.46) N=22	0.68 (0.48 N=25	0.47 (0.51) N=17	0.64 (0.48) N=64
Expository	0.82 (0.39) N=17	0.76 (0.44) N=21	0.64 (0.49) N=22	0.73 (0.45) N=60
Total Popul.	0.77 (0.43) N=39	0.72 (0.46) N=46	0.56 (0.50) N=39	

TABLE 6.10(a) TWO-WAY ANOVA ON THE ADDITIONAL EXERCISE SCORE WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (HFT) AND INSTRUCTIONAL MODES.

Source of Variable	df	Mean Square	F-ratio	Signif. Level p≤
Field Independence/dependence	2	0.51	2.36	N.S
Instructional Modes	1	0.39	1.80	N.S
Interaction	2	0.02	0.09	N.S
Residual	118	0.22		

TABLE 6.10(b) TWO-WAY ANCOVA ON THE ADDITIONAL EXERCISE SCORE WITH RESPECT TO LEVELS OF FIELD INDEPENDENCE (HFT) AND INSTRUCTIONAL MODES.

Source of Variable	df	Mean Square	F-ratio	Signif. Level p≤
Field Independence/dependence	2	0.28	1.32	N.S
Instructional Modes	1	0.54	2.57	N.S
Interaction	2	0.04	0.17	N.S
Residual	109	0.21		

instructional modes in favour of the field independent group. The analysis of variance failed to reveal any statistical significant difference between the groups. This may be due to the relatively high mean score of the intermediate group which is higher than expected.

Conclusion

On the whole the result of the present investigation with respect to field independence/dependence as a cognitive style has a moderate influence on chemistry learning. Field independent subjects perform relatively better than field dependent subjects in both discovery and expository learning, even after partialling out the IQ effect. The result with respect to the expository teaching mode seems to indicate that exposition of rules and principles to be learned is not sufficient to compensate for the low tendency on the part of field dependent subjects to analyse and incorporate new ideas into their cognitive structures. This view is supported by the findings of Satterley and Telfer (1979) who found that providing advance organisers by itself did not facilitate learning and retention for field dependent students but it helped when the teacher deliberately emphasised its properties at a number of points during the course of the lesson. This suggests that in order to foster meaningful learning by field dependent learners, a deliberate attempt must be made to point out to them the potential of the organisers, rules or principles, during the learning process. Also, it may be argued that field dependent learners need more direction and help from the teacher during the learning process, and hence individualised learning programmes may appear to be less suitable for field dependent learners than for field independent learners. This view is in keeping with the characterisation of field dependent persons by Witkin (1974), as "persons who rely on others for guidance and support."

6.33 Conceptualisation styles and chemistry learning

The same three conceptualisation styles as used in the Phase I study (inferential, descriptive and relational) were considered here, but in relation to chemistry learning task. The results are presented and discussed under separate subheadings dealing, respectively, with the inferential style, the descriptive style and the relational style. In each section an analysis of the performance in the post-learning tasks are presented. A general summary of the finding is presented at the end of these subsections.

a) Inferential Conceptualisation Style

Part (i) Application of Rules Variables

Since conceptualisation styles scores were available for only 47 subjects only two subgroups were formed for the analysis. Students scoring below 62 on the inferential scale were allocated to the 'low inferential' group and students scoring 62 and above to the 'high inferential' group, (score range 42 to 72). Students' scores on this set of variables were anlaysed using the t-test analysis procedure. Table 6.11 reports the mean scores, and the standard deviations achieved by the two groups on the various application of rules tasks together with the results of the t-test analyses.

In the Unit 1 and Unit 3 tasks, the high inferential thinkers performed significantly better than low inferential thinkers. Although these results would support the initial hypothesis that high inferential thinkers should have an advantage over low inferential thinkers in learning by discovery, this is not upheld by the results from Units 2 and 4, where the low inferential thinkers appear to have performed somewhat better. It should be noted, though, that for the latter two units the variability of scores within the groups is very high. This may be a possible explanation for the rather unusual and unexpected result. The

TABLE 6.11 MEAN SCORES STANDARD DEVIATIONS ON APPLICATION OF RULES VARIABLES AND RESULTS OF t-TEST ANALYSES (INFERENTIAL CONCEPTUALISATION STYLE).

Application of Rules Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Unit 1 (11)	Low Inferential N=11	9.73 (2.41)	1.91	N.S
	High Inferential N=13	11.00 (0.00)		
Unit 2 (18)	Low Inferential N=12	11.33 (8.18)	0.39	N.S
	High Inferential N=11	10.00 (8.17)		
Unit 3 (6)	Low Inferential N=11	0.73 (0.79)	4.48	0.001
	High Inferential N=13	3.77 (2.13)		
Unit 4 (32)	Low Inferential N=11	17.82 (9.02)	1.40	N.S
	High Inferential N=11	12.00 (10.40)		

TABLE 6.12 MEAN SCORES STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 AND RESULT OF THE t-TEST ANALYSIS (INFERENTIAL CONCEPTUALISATION STYLE).

Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Additional Exercise Unit 1 (1)	Low Inferential N=11	0.36 (0.51)	2.11	0.05
	High Inferential N=13	0.77 (0.44)		

nature of the Unit 2 and Unit 4 tasks does not suggest any apparent inherent difference, compared with the Unit 3 task.

Part (ii) Additional exercise - Unit 1

Table 6.12 presents the basic data for this variable and the result of the t-test analysis.

The result shows that the high inferential group has done significantly better than the low inferential group. The t-test reveals that this difference in performance is significant at the 5% level. It must be remembered that this task required more than the mere recall of the facts learned in the unit, i.e., it required students to infer a relationship beyond the immediate facts learned in the unit. As such it is a discovery task itself and therefore, the high inferential thinkers should perform better than low inferential thinkers. The result is in support of the hypothesis.

b) Descriptive Conceptualisation Style

Part (i) Application of Rules Variables

As in the above analysis, students were divided into two groups (low and high) according to their scores on the descriptive conceptualisation scale. A t-test analysis was performed on the scores achieved by the two groups on each of the application tasks associated with the four learning units. Table 6.13 reports the mean scores, and the standard deviations and the results of the t-test analyses.

In general no significant difference in performance is observed between the low and high descriptive groups in relation to this set of tasks. This result is in agreement with the finding in the Phase I study where descriptive conceptualisation style showed no significant variation with success in learning outcome via the discovery mode in verbal tasks (scrambled words, and coded words).

TABLE 6.13 MEAN SCORES, STANDARD DEVIATIONS ON APPLICATION OF RULES VARIABLES AND RESULTS OF t-TEST ANALYSIS (DESCRIPTIVE CONCEPTUALISATION STYLE).

Application of Rules Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Unit 1 (11)	Low Descriptive N=10	10.60 (1.65)	0.43	N.S
	High Descriptive N=14	10.28 (1.82)		
Unit 2 (18)	Low Descriptive N=13	10.69 (8.48)	0.0	N.S
	High Descriptive N=10	10.70 (7.83)		
Unit 3 (6)	Low Descriptive N=10	2.80 (1.87)	0.78	N.S
	High Descriptive N=14	2.07 (2.50)		
Unit 4 (32)	Low Descriptive N=12	11.75 (8.98)	1.70	N.S
	High Descriptive N=10	18.70 (10.18)		

TABLE 6.14 MEAN SCORES, STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 AND RESULT OF THE t-TEST ANALYSIS (DESCRIPTIVE CONCEPTUALISATION STYLE).

Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Additional exercise Unit 1 (1)	Low Descriptive N=10	0.60 (0.52)	0.13	N.S
	High Descriptive N=14	0.57 (0.51)		

Part (ii) Additional exercise - Unit 1

Table 6.14 presents the mean scores, the standard deviations and the result of the t-test analysis. The descriptive thinking mode is again found to have no significant bearing on learning outcome in relation to this task. This result further supports the finding in the Phase I study and the general lack of relationship between descriptive thinking and the performance in the application of rules tasks observed in part (i).

c) Relational Conceptualisation Style

Part (i) Application of Rules Variables

As in the above two analyses, t-test analyses were carried out on the mean scores achieved by the low and high relational style group on the various application of rules tasks. Table 6.15 presents the relevant data.

It will be remembered in relation to Phase I study a moderate inverse relationship was established between relational style and leaning outcome. The results obtained do not show a uniform trend. Whilst in Units 1 and 3, the low relational thinkers have performed better than the high relational thinkers, in Units 2 and 4 the opposite seems to be the case. However, in no case is an acceptable statistical significance level reached and, hence, the conclusion to be drawn is that no firm relationship appears to exist between relational thinking style and learning outcome.

Part (ii) Additional exercise - Unit 1

Table 6.16 reports the mean scores, the standard deviations and the result of the t-test analysis. Although the low relational thinkers appear to have done marginally better than high relational thinkers, the difference is not statistically significant.

TABLE 6.15 MEAN SCORES, STANDARD DEVIATIONS ON APPLICATION OF RULES VARIABLES AND RESULTS OF t-TEST ANALYSIS (RELATIONAL CONCEPTUALISATION STYLE).

Application of Rules Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Unit 1 (11)	Low Relational N=16	10.69 (1.25)	1.10	N.S
	High Relational N=8	9.88 (2.42)		
Unit 2 (18)	Low Relational N=9	8.11 (7.85)	1.26	N.S
	High Relational N=14	12.36 (7.96)		
Unit 3 (6)	Low Relational N=16	2.88 (2.55)	1.60	N.S
	High Relational N=8	1.38 (0.92)		
Unit 4 (32)	Low Relational N=9	13.33 (9.95)	0.61	N.S
	High Relational N=13	16.00 (10.21)		

TABLE 6.16 MEAN SCORES, STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 AND RESULT OF THE t-TEST ANALYSIS (RELATIONAL CONCEPTUALISATION STYLE).

Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t -value	Two-tailed Prob.
Additional exercise Unit 1 (1)	Low Relational N=16	0.63 (0.50)	0.56	N.S
	High Relational N=8	0.50 (0.53)		

General Conclusion

The results of the Phase II study essentially confirm the conclusion derived from the Phase I investigation, which is that of the three conceptualisation styles only the inferential thinking mode appears to have some direct bearing upon learning by the discovery mode. The situation is basically that the higher an individual's leaning towards inferential thinking, the higher is his success rate in discovery learning. Neither the descriptive nor the relational thinking modes appear to have any significant bearing on students' learning behaviour in discovery situations. Thus, only the inferential thinking mode can be recognised as a cognitive style which influences learning by discovery.

6.34 Conceptual differentiation and chemistry learning

Students' scores on the various post-learning tasks were analysed using the t-test analysis procedure. For this purpose, the students were divided into two groups, high and low differentiators, according to their scores in the Object Sorting Test. Those who score above the median were defined as 'high differentiators' and those who score below the median as 'low differentiators'. The results are reported in two parts as in the earlier sections.

Part (i) Application of Rules Variables

Table 6.17 presents the mean scores, the standard deviations achieved by the two groups on the various application exercises and the results of the t-test analyses.

The data shown in Table 6.17 reveal that no significant differences exist between the performances the high and low differentiators. This finding is in agreement with that reached in the Phase I study where the degree of conceptual differentiation was found to have no significant relation to learning by discovery.

TABLE 6.17 MEAN SCORES, STANDARD DEVIATIONS ON APPLICATION OF RULES VARIABLES AND RESULTS OF t-TEST ANALYSIS (CONCEPTUAL DIFFERENTIATION STYLE).

Application of Rules Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Unit 1 (11)	Low Differentiators N=20	9.90 (2.83)	1.05	N.S
	High Differentiators N=19	10.63 (1.16)		
Unit 2 (18)	Low Differentiators N=21	12.33 (7.86)	1.02	N.S
	High Differentiators N=16	9.69 (7.70)		
Unit 3 (6)	Low Differentiators N=20	2.85 (2.48)	0.82	N.S
	High Differentiators N=20	2.20 (2.55)		
Unit 4 (32)	Low Differentiators N=20	14.35 (11.31)	0.50	N.S
	High Differentiators N=16	16.13 (9.56)		

TABLE 6.18 MEAN SCORES, STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 AND RESULT OF THE t-TEST ANALYSIS (CONCEPTUAL DIFFERENTIATION STYLE).

Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t-value	Two-tailed Prob.
Additional exercise Unit 1 (1)	Low Differentiators N=20	0.60 (0.50)	0.54	N.S
	High Differentiators N=19	0.68 (0.48)		

Part (ii) Additional exercise - Unit 1

Table 6.18 presents the relevant data for this exercise.

As in the above set of variables, no significant difference in performance was found between the high and low differentiation group in relation to this task. This provides further evidence for the view that conceptual differentiation has little bearing on learning behaviour by discovery mode.

General Conclusion

As stated in Chapter 2, conceptual differentiation appears to be a cognitive style that involves the analysis of arrays of stimuli for the purpose of dividing them into small groups. It does not involve the process of formulation or abstraction of concept, contrary to the interpretation of this style that has sometimes been suggested. Since the formulation of patterns is the key issue in concept attainment, the apparent absence of any direct relationship between the conceptual differentiation style and students' learning from discovery situations seems entirely in keeping with the theoretical considerations developed previously.

6.35 Convergency-divergency and chemistry learning

For this analysis the students were divided into two groups, convergent thinkers and divergent thinkers, according to their scores on the flexibility scale (Uses of Objects Test). Those who scored above the median were defined as divergent thinkers and those who score below the median as convergent thinkers. The students' scores on the various post-learning tasks were anlaysed using the t-test analysis procedure. The results are presented in two parts as in the previous sections.

Part (i) Application of Rules Variables

Table 6.19 presents the mean scores, the standard deviations achieved by the divergent and convergent thinkers on the various application of rules variables and the results of the t-test analyses.

As is seen, there is very little difference in the performance level of the divergent and convergent thinkers in relation to the Unit 1 task. One possible explanation for this is the high performance of both groups on this task: this is in excess of 85 per cent of the maximum score possible. In Unit 2 and Unit 4, the divergent thinkers would appear to have done better than convergent thinkers, but in neither case is the difference between the performance means sufficiently large to reach an acceptable statistical significance level.

For the Unit 3 task, the performance of the convergent thinkers is found to be superior to that of the divergent thinkers, the difference being significant at the 2% level. Whilst this would support the initial hypothesis that convergent thinkers should do better in discovery learning than divergent thinkers, the results from the Unit 2 and 4 tasks must cast some doubt on this.

Part (ii) Additional exercise - Unit 1

Table 6.20 presents the mean score, the standard deviation achieved by the groups in this exercise and the result of the t-test analysis. No significant difference in the performance levels is observed between the convergent thinkers and divergent thinkers. This may be partly due to the high variability in the scores within the groups as indicated by the large standard deviations. At any rate, any hypothesis about a higher performance of convergers is not supported by the data.

General Conclusion

As in the case of the Phase I study, the result concerning the effect of the convergency-divergency mode obtained in Phase II do not allow any firm conclusions to be drawn about the effect of this style upon students' learning behaviour. Only in one of the tasks was a result obtained that

TABLE 6.19 MEAN SCORES, STANDARD DEVIATIONS ON APPLICATION OF RULES VARIABLES AND RESULTS OF t-TEST ANALYSIS (CONVERGENCY-DIVERGENCY STYLE).

Application of Rules Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t -value	Two-tailed Prob.
Unit 1 (11)	Convergent N=22	9.41 (3.02)	0.87	N.S
	Divergent N=23	10.13 (2.56)		
Unit 2 (18)	Convergent N=22	9.36 (7.59)	1.44	N.S
	Divergent N=14	13.07 (7.43)		
Unit 3 (6)	Convergent N=22	3.45 (2.06)	2.55	0.05
	Divergent N=22	1.73 (2.41)		
Unit 4 (32)	Convergent N=21	11.14 (9.52)	0.69	N.S
	Divergent N=14	13.64 (11.90)		

TABLE 6.20 MEAN SCORES, STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 AND RESULTS OF t-TEST ANALYSIS (CONVERGENCY-DIVERGENCY STYLE).

Variable (Max. Score)	Subgroup	Mean Score (Std. Dev.)	t -value	Two-tailed Prob.
Additional Exercise Unit 1 (1)	Convergent N=22	0.55 (0.51)	0.72	N.S
	Divergent N=23	0.65 (0.48)		

lent support to the notion that convergent thinkers should do better than divergent thinkers in discovery learning situations. Other tasks failed to confirm this. It has to be admitted that the learning and testing tasks used in the Units had not been specifically designed to test the possible effects of the convergency/divergency style on learning. It may be that with more appropriate learning tasks which allow alternative solutions to be produced (as suggested in Chapter 2) a clearer picture can be reached regarding the influence of convergency-divergency on learning behaviour, but this would be the theme of a further study.

6.36 Reflectivity-impulsivity and chemistry learning

This cognitive style was examined only in relation to chemistry learning. Students' latency scores on the Matching Familiar Figures Test were used as the criterion measure of their reflective or impulsive character, for the reasons already stated in Chapter 4. This measure was available for 76 subjects. The students were divided into two groups along the median score. Students scoring below the median score were defined as reflective and those above the median score as impulsive.

Students' scores on the various post-learning tasks were analysed using the two-way analysis of variance procedure, with respect to both the reflectivity-impulsivity style and the instructional mode. This was done because it was hypothesised that reflectivity-impulsivity would have a bearing on learning outcome from both the discovery mode and the expository mode. The results are presented below.

Part (i) Application of Rules Variables

Table 6.21 presents the basic data, whilst Table 6.22 summaries the results of the two-way analyses of variance.

TABLE 6.21 MEAN SCORES AND STANDARD DEVIATIONS ON THE APPLICATION OF RULES VARIABLES (REFLECTIVITY-IMPULSIVITY - LATENCY SCALE).

Application of Rules Variable (Max. Score)	Instructional Mode	Performance Score of Subgroups		Total Popul.
		Impulsive	Reflective	
Unit 1 (11)	Discovery	9.76 (2.86) N=21	8.84 (3.69) N=19	9.33 (3.27) N=40
	Expository	9.35 (3.72) N=17	9.89 (2.86) N=19	9.64 (3.26) N=36
	Total Popul.	9.58 (3.24) N=38	9.37 (3.30) N=38	
Unit 2 (18)	Discovery	12.18 (7.26) N=17	8.26 (7.86) N=19	10.11 (7.73) N=36
	Expository	14.52 (5.64) N=21	15.32 (5.15) N=19	14.90 (5.36) N=40
	Total Popul.	13.47 (6.43) N=38	11.79 (7.47) N=38	
Unit 3 (6)	Discovery	3.05 (2.39) N=20	2.89 (2.60) N=19	2.97 (2.46) N=39
	Expository	3.88 (2.34) N=17	3.74 (2.42) N=19	3.81 (2.35) N=36
	Total Popul.	3.34 (2.41) N=37	3.31 (2.52) N=38	
Unit 4 (32)	Discovery	14.76 (12.03) N=17	12.58 (8.99) N=19	13.61 (10.44) N=36
	Expository	17.80 (9.18) N=20	16.00 (10.68) N=19	16.92 (9.85) N=39
	Total Popul.	16.41 (10.74) N=37	14.29 (9.89) N=38	

TABLE 6.22 TWO-WAY ANALYSES OF VARIANCE ON ACHIEVEMENT SCORES (APPLICATION OF RULES VARIABLES) WITH RESPECT TO REFLECTIVITY-IMPULSIVITY AND INSTRUCTIONAL MODES.

Variable	Source of Variance	df	Mean Square	F-ratio	Signif. Level $p \leq$
Application of Rules Unit 1	Reflectivity-impulsivity	1	0.98	0.09	N.S
	Instructional Modes	1	2.01	0.19	N.S
	Interaction	1	10.09	0.93	N.S
	Residual	72	10.80		
Application of Rules Unit 2	Reflectivity-impulsivity	1	39.08	0.92	N.S
	Instructional Modes	1	419.71	9.85	0.01
	Interaction	1	104.58	2.45	N.S
	Residual	72	42.63		
Application of Rules Unit 3	Reflectivity-impulsivity	1	0.42	0.07	N.S
	Instructional Modes	1	13.10	2.19	N.S
	Interaction	1	0.00	0.00	N.S
	Residual	71	5.97		
Application of Rules Unit 4	Reflectivity-impulsivity	1	73.74	0.71	N.S
	Instructional Modes	1	195.15	1.87	N.S
	Interaction	1	0.70	0.01	N.S
	Residual	71	104.63		

The two-way ANOVA performed on the data obtained from the four application tasks revealed that no significant interaction exists between the reflectivity-impulsivity mode on the one hand and the modes of instruction used (discovery/expository) on the other. Also, with respect to the main effect of the reflectivity-impulsivity style on learning outcome, no significant relationship is observed. Further examination of the data in relation of discovery learning and expository teaching does not reveal any marked trend in favour of reflective or impulsive group. Therefore, it appears that reflectivity-impulsivity as a cognitive style has little bearing on learning outcome, at least for the chemistry tasks used in the present study.

Part (ii) Additional exercise - Unit 1

Table 6.23 presents the basic data and the 2-way ANOVA results are reported in Table 6.24. Again, no interaction is observed between reflectiviey-impulsivity and instructional modes. Likewise, the main effect of the cognitive style on learning outcome does not show any distinction between reflective and impulsive learners. This result is in agreement with that in Part (i).

A second analysis was performed in which the subjects were classified as reflective and impulsive using the double median split technique i.e., subjects scoring above the median in the latency score and below the median in the error score were defined as reflective, and students scoring below the median in the latency score and above the median in the error score were defined as impulsive. The results were very similar to the first analysis, again showing no significant relationship between reflectivity-impulsivity and learning outcome/instructional modes.

General Conclusion

Although it was hypothesised that reflective individuals would have an

TABLE 6.23 MEAN SCORES AND STANDARD DEVIATIONS ON THE ADDITIONAL EXERCISE IN UNIT 1 (REFLECTIVITY-IMPULSIVITY - LATENCY SCALE).

Variable (Max. Score)	Instructional Mode	Performance Score of Subgroup		Total Popul.
		Impulsive	Reflective	
Additional exercise Unit 1 (1)	Discovery	0.62 (0.50) N=21	0.58 (0.51) N=19	0.60 (0.50) N=40
	Expository	0.71 (0.47) N=17	0.68 (0.48) N=19	0.69 (0.47) N=36
	Total Popul.	0.65 (0.48) N=38	0.63 (0.49) N=38	

TABLE 6.24 TWO-WAY ANALYSIS OF VARIANCE ON THE ADDITIONAL EXERCISE SCORE WITH RESPECT TO REFLECTIVITY-IMPULSIVITY AND INSTRUCTIONAL MODES.

Source of Variance	df	Mean Square	F-ratio	Signif. Level p$\leq$
Reflectivity-Impulsivity	1	0.02	0.08	N.S
Instructional Modes	1	0.17	0.73	N.S
Interaction	1	0.00	0.01	N.S
Residual	72	0.24		

advantage over impulsive individuals in learning in general and more so in discovery learning, the results of the present study do not support the hypothesis. A likely explanation for this is that the tasks used in the present study were intrinsically unsuitable for the purpose of producing discernable differences between the learning behaviours of impulsive and reflective students. In the learning units, students were presented with a set of tasks that is essentially different in terms of intellectual requirements from the Matching Familiar Figures exercises. The latter are more of a perceptual nature whilst the chemistry learning tasks requires organisation of information and the abstraction of pattern therefrom. It may be that the reflectivity-impulsivity style has a more significant bearing on task performance in situations where information perception is a significant component. This would have to be examined by a separate study.

6.4 SUMMARY AND CONCLUSIONS

In addition to the examination of the effects of cognitive styles on learning outcomes with respect to short decoding and serial tasks in the Phase I study, the Phase II study was designed to examine the effect of five cognitive styles on chemistry learning.

a) As in the Phase I study it was found that the field independence/dependence style has an effect on learning from both the discovery and expository situations. This effect is significant even after partialling out the influence of IQ.

b) The results of the Phase II study with respect to the conceptualisation styles essentially confirmed the findings in the Phase I study, i.e. only the inferential conceptualisation style has any significant bearing on learning from the discovery mode.

c) The Phase II study also confirmed the apparent absence of any direct relationship between the conceptual differentiation style and students' learning behaviour in discovery situations found in the Phase I study. This finding appears to suggest that conceptual differentiation does not involve the process of abstraction and formulation of concepts contrary to the interpretation of this style that has sometimes been suggested.

d) Convergency-divergency style and the reflectivity-impulsivity style showed no significant effect on learning outcome in the context of the present study.

In conclusion it may be said that field independence/field dependence and inferential conceptualisation are cognitive style variables which affect learning outcomes. Hence, knowledge of students' leanings towards field independence/dependence style and inferential thinking would be a valuable aid in the design of learning material and the selection of teaching methods.

CHAPTER 7 RELATIONSHIP BETWEEN COGNITIVE STYLES LEANING AND PREFERENCE FOR LEARNING TYPES

7.0 INTRODUCTION

In addition to the study of the relationship between students' cognitive styles and their learning behaviour in situations involving either discovery or expository learning, the relationship between students' cognitive styles and their preference for the two instructional modes was also examined as part of Phase I study. This investigation was conducted with respect to two constructs, viz. the relative ease or difficulty of the two instructional modes as perceived by students, and the satisfaction or enjoyment which they derived from them. As already described in Chapter 3, a rating schedule was developed for the purpose of assessing the two constructs, using two sets of semantic differential items.

In this chapter, the results of the investigation are reported. Initially, an account is given of students' perceptions of the ease/difficulty and enjoyment of the two instructional approaches, without examining the association of cognitive styles with these perceptions. Thereafter, the differential effect of the cognitive styles is examined in detail.

7.1 GENERAL VIEWS ON DISCOVERY AND EXPOSITORY LEARNING

7.11 Ease/Difficulty Scale

The scale used for the measurement of the ease/difficulty of the instructional approaches gave scores which essentially expressed students' perception of the difficulty of each learning mode. This means that a high score points to a high perceived level of difficulty, whilst a low score is indicative of the instructional approach being found easy. Table 7.1 presents the mean ratings and standard deviations achieved by the total sample on the ease/difficulty scale, for both the discovery and the expository learning mode. Also shown in the table is the result of the paired t-test on the data.

As is seen from the mean ratings, students perceive learning from discovery situation to be significantly more difficult than learning from expository situation. This result should not cause surprise: involvement in discovery requires students to abstract from information provided, patterns or rules implied in the information on their own. This is a task which is intrinsically more demanding and, hence, difficult than the more passive form of reception learning which is the essence of the expository approach. Evidently, students - on comparing the two instructional approaches - find the discovery mode significantly more difficult than the expository mode.

7.12 Enjoyment/Dislike Scale

The scale used for the measurement of the enjoyment of/dislike for the instructional approaches gave scores which expressed student's dislike for the instructional procedures. In other words, a high score points to a high level of dislike whilst a low score is indicative of the instructional approach being found enjoyable or satisfying. Table 7.2 reports the mean ratings and standard deviations achieved by the total sample on the enjoyment/dislike scale for both the discovery and the expository learning mode. Also, shown in the table is the result of the t-test on the data.

In terms of enjoyment and satisfaction derived from the two types of instruction, learning by discovery appears to be preferred to learning from expository situations. Although this finding is statistically significant at the 1% level, it is worth noting that the difference is

TABLE 7.1 MEAN RATINGS, STANDARD DEVIATIONS ON EASE/DIFFICULTY SCALE AND RESULT OF t-TEST ANALYSIS (N=275).

Instructional Mode	Mean Rating	Std. Dev.	t-value	One-tailed Prob.
Discovery	17.97	6.95	8.66	0.001
Expository	12.62	7.43		

Score Range Max = 30, Min = 5.

TABLE 7.2 MEAN RATINGS, STANDARD DEVIATIONS ON ENJOYMENT/ DISLIKE SCALE AND RESULT OF t-TEST ANALYSIS (N=275).

Instructional Mode	Mean Rating	Std. Dev.	t-value	One-tailed Prob.
Discovery	23.22	8.08	2.55	0.01
Expository	24.57	8.02		

Score Range Max = 36, Min = 6.

really quite small, and certainly smaller than might have been expected in view of the claim, often made, that discovery learning has a major motivating effect.

7.2 EFFECT OF COGNITIVE STYLES OF STUDENTS' PERCEPTION OF EASE AND ENJOYMENT OF THE INSTRUCTIONAL MODES

The important issue when examining the influence of cognitive styles upon students' perception of the ease/difficulty or enjoyableness of discovery or expository instructional modes, is to obtain an indication of the relative ratings attached to the modes, not their absolute ratings. To amplify this: the question is not whether, say, field independent persons prefer the discovery mode to the expository mode, but whether they do so proportionately more than field dependent persons.

To achieve this, differences in rating scores in the perception variables have to be considered, rather than their absolute values. These differences were defined as follows:-

i) For the difficulty scale:

Perceived difference in the difficulty rating = difficulty value (discovery mode) - difficulty value (expository mode)

ii) For the enjoyableness scale:

Perceived difference in the enjoyment rating = enjoyment value (discovery mode) - enjoyment value (expository mode)

On the above measures the ease/difficulty scale ranged from -30 to +30 and the enjoyment/dislike scale ranged from -36 to +36. In relation to the ease/difficulty scale, the higher the score difference calculated (in the positive direction), the greater is the difficulty associated with discovery learning compared with learning from expository instruction. In relation to the enjoyment/dislike scale, the larger (more positive) the score difference, the greater is the dislike for discovery learning compared with learning from expository situations. Conversely, the smaller the score difference (more negative), the more is discovery preferred to expository in terms of enjoyment.

The results of the analyses in relation to each of the cognitive styles variables are presented in separate sections below.

7.21 Field independence/dependence and Students' Perception of the Ease and Enjoyableness of the Instructional Modes

Table 7.3 presents the mean ratings and standard deviations achieved by the field independent (FI) and field dependent (FD) subjects on the comparative difficulty and enjoyment scales, together with the results of the t-test analyses.

The mean ratings on the ease/difficulty scale are positive for both groups. This is in line with the previous finding that both groups perceive discovery mode to be more difficult than expository mode. However, there is no significant difference between the means, and therefore no differential effect of the field independence style on the perception of the ease/difficulty of the two instructional modes exists. The initial hypothesis that field dependent persons should perceive discovery learning relative more difficult than field independent persons, (cf. Chapter 2, section 2.61) is thus not borne out. One reason for this might lie in the fact that the teaching units used in this study were presented in a self-instructional format. Field dependent persons are generally more socially orientated than field independent persons, and so would perceive the self-instructional format as relatively more difficult than teacher-based instruction (because of an absence of "personal touch"). This might counteract any greater ease which they might have associated with the actual learning from expository situation. The overall effect could therefore be the

TABLE 7.3 MEAN RATINGS, STANDARD DEVIATIONS ON COMPARATIVE SCALES, AND RESULTS OF t-TEST ANALYSES (FIELD INDEPENDENCE/ DEPENDENCE STYLE).

Variable (Score Range)	Subgroup	Mean Rating (Std. Dev.)	t-value	One-tailed Prob.
Ease/Difficulty (Max=+30, Min=-30)	Field Dependent	5.61 (10.71)	0.33	N.S
	Field Independent	5.19 (9.79)		
Enjoyment/Dislike (Max=+36, Min=-36)	Field Dependent	-0.18 (8.29)	-2.35	0.01
	Field Independent	-2.69 (9.27)		

TABLE 7.4 MEAN RATINGS, STANDARD DEVIATIONS ON COMPARATIVE SCALES, AND RESULTS OF t-TEST ANALYSES (INFERENTIAL CONCEPTUALISATION STYLE).

Variable (Score Range)	Subgroup	Mean Rating (Std. Dev.)	t-value	One-tailed Prob.
Ease/Difficulty (Max=+30, Min=-30)	Low Inferential	4.78 (9.34)	0.05	N.S
	High Inferential	4.04 (10.22)		
Enjoyment/Dislike (Max=+36, Min=-36)	Low Inferential	0.02 (8.08)	2.39	0.01
	High Inferential	-3.02 (8.73)		

absence of a discernable advantage or disadvantage. It must be said, however, that this is a largely speculative argument.

In relation to the comparative enjoyment scale, the field dependent group has produced a lower score difference value than the field independent group. This means that the field dependent group has expressed a stronger dislike of discovery learning than the field independent group. Conversely, it could be argued that the latter type of student finds discovery learning more enjoyable than the former. The differentiation is statistically significant at the 1% level. This finding is not inconsistent with the assumption each group is preferentially attracted to the instructional mode which closest matches its cognitive behaviour and style. Thus, field dependent who have a low inclination only towards situations demanding information to be abstracted, structured and sythesised, should find discovery learning less satisfying and less enjoyable than their counterparts, and vice versa.

7.22 Conceptualisation styles and Students' Perception of the Ease and Enjoyableness of the Instructional Modes

As elsewhere, the results concerning the three conceptualisation styles are presented and discussed under three separate subheadings dealing, respectively, with the inferential, the descriptive and the relational style.

i) Inferential conceptualisation style and comparative ratings of the instructional modes

Table 7.4 presents the basic data and the results of the t-test analyses relating to the comparative ease/difficulty and the enjoyment/dislike scale. It can be seen from the table that there is very little difference between the comparative mean ratings of the low and high inferential thinkers on the ease/difficulty scale. Thus, no differentiation appears between students, in terms of their inferential conceptualisation style, on the perception of ease or difficulty the two modes of instruction. Although it might have been assumed that high inferential thinkers would find discovery learning relatively less difficult than low inferential thinkers (cf. Chapter 2, section 2.62), this is not borne out by the present data.

In relation to the enjoyment/dislike scale the low inferential thinkers show a signficantly more positive rating than the high inferential thinkers. Thus, low inferential thinkers express a greater dislike for learning by discovery than do high inferential thinkers, or vice versa. This finding is again in line with the initial hypothesis that students should feel most closely attracted to the type of instruction which matches their cognitive styles leaning best. In the present case, the inferential thinkers evidently prefer the discovery mode with its demand for the abstraction and structuring of information.

ii) Descriptive conceptualisation style and comparative ratings of instructional modes

Table 7.5 presents the basic data and the results of the t-test analyses.

As for the inferential conceptualisation style, there is no significant difference between the mean comparative ratings of the low and high descriptive groups on the ease/difficulty scale. Therefore, it may be concluded that the descriptive style, like the inferential style, does not have a differential bearing on students' perception of the ease or difficulty of the two instructional modes.

In relation to the enjoyment/dislike scale, a difference exists between the mean comparative ratings of the low and high group, with the high descriptive group having a more positive score, i.e., expressing less satisfaction with discovery learning, than the low descriptive thinkers.

TABLE 7.5 MEAN RATINGS, STANDARD DEVIATIONS ON COMPARATIVE SCALES, AND RESULTS OF t-TEST ANALYSES (DESCRIPTIVE CONCEPTUALISATION STYLE).

Variable (Score Range)	Subgroup	Mean Rating (Std. Dev.)	t-value	One-tailed Prob.
Ease/Difficulty (Max=+30, Min=-30)	Low Descriptive	4.57 (10.15)	0.21	N.S
	High Descriptive	4.26 (9.43)		
Enjoyment/Dislike (Max=+36, Min=-36)	Low Descriptive	-2.55 (8.72)	-1.64	0.051
	High Descriptive	-0.43 (8.23)		

TABLE 7.6 MEAN RATINGS, STANDARD DEVIATIONS ON COMPARATIVE SCALES, AND RESULTS OF t-TEST ANALYSES (RELATIONAL CONCEPTUALISATION STYLE).

Variable (Score Range)	Subgroup	Mean Rating (Std. Dev.)	t-value	One-tailed Prob.
Ease/Difficulty (Max=+30, Min=-30)	Low Relational	3.62 (10.96)	-1.17	N.S
	High Relational	5.35 (8.12)		
Enjoyment/Dislike (Max=+36, Min=-36)	Low Relational	-2.53 (9.15)	-1.74	0.05
	High Relational	-0.29 (7.61)		

This difference is only just reaching the 5% level of significance, and thus a relatively "weak" finding. Interestingly, the observed differential is not in line with the initial prediction according to which individuals with a high descriptive style would perceive discovery learning as more enjoyable than low descriptive style individuals. A likely explanation for this is that the previous finding about the association of the comparative enjoyment rating with the inferential thinking style masks any association between that rating and the descriptive style: due to the ipsative nature of the scores on the conceptualisation styles test, negative correlations exist between the various styles measures. For the inferential and descriptive styles, the calculated correlation is $r = -0.39$.

iii) Relational conceptualisation style and comparative ratings of the instructional modes

Table 7.6 presents the basic data and the results of the t-test analyses. It is seen that the high relational group perceived discovery learning as marginally more difficult than the low relational group, but the difference in the mean ratings is not significant at the 5% level.

On the comparative enjoyment/dislike scale, the high relational group has a mean ratings which is slightly more positive than that of the low relational group. Therefore, it may be suggested that high relational thinkers, compared with low relational thinkers perceive discovery learning as somewhat less enjoyable or less satisfying than learning by exposition. In absolute terms, this difference is rather small, despite the fact that it reaches the 5% significance level. Bearing in mind the ipsative nature of the conceptualisation styles scores, it would be probably be unwise to attach a deep meaning to the present result.

7.23 Conceptual Differentiation and Students' Perception of the Ease and Enjoyableness of the instructional modes

Table 7.7 presents the basic data and the results of the t-test analyses with respect to conceptual differentiation cognitive style. The data indicate that high conceptual differentiations perceive discovery learning to be comparatively more difficulty than learning from expository teaching. The differentiation is significant at the 5% level. Only a tentative explanation can be suggested for this: high differentiators, it may be argued have a low tendency to develop broad classification patterns in which they bring together large numbers of stimuli. This type of pattern formation and recognition would of course be a major ingredient of successful learning from open-ended discovery situations. Thus, it is plausible that high differentiators should perceive discovery learning more difficult than learning from exposition.

In relation to the enjoyment/dislike scale, there is no significant difference in the mean comparative rating of the two groups. Hence, it appears the leaning of a person on the conceptual differentiation cognitive dimension has no influence on the perception of the relative enjoyableness of the two modes of instruction.

7.24 Convergency-Divergency and Students' Perception of the Ease and Enjoyableness of the instructional modes

Table 7.8 presents the basic data and the results of t-test analyses relating to both ease/difficulty and enjoyment/dislike scale, in relation to the convergency/divergency style.

It can be seen that there is a small, but significant difference in the comparative mean ratings of the convergent and divergent thinkers on the ease/difficulty scale. The divergent thinkers have perceived

TABLE 7.7 MEAN RATINGS, STANDARD DEVIATIONS ON COMPARATIVE SCALES, AND RESULTS OF t-TEST ANALYSES (CONCEPTUAL DIFFERENTIATION STYLE).

Variable (Score Range)	Subgroup	Mean Rating (Std. Dev.)	t-value	One-tailed Prob.
Ease/Difficulty (Max=+30, Min=-30)	Low Differentiation	3.11 (10.47)	-1.82	0.05
	High Differentiation	5.58 (8.50)		
Enjoyment/Dislike (Max=+36, Min=-36)	Low Differentiation	-1.30 (7.55)	0.17	N.S
	High Differentiation	-1.51 (9.06)		

TABLE 7.8 MEAN RATINGS, STANDARD DEVIATIONS ON COMPARATIVE SCALES, AND RESULTS OF t-TEST ANALYSES (CONVERGENCY-DIVERGENCY STYLE).

Variable (Score Range)	Subgroup	Mean Rating (Std. Dev.)	t-value	One-tailed Prob.
Ease/Difficulty (Max=+30, Min=-30)	Convergent	4.33 (11.01)	-1.69	0.05
	Divergent	6.72 (10.35)		
Enjoyment/Dislike (Max=+36, Min=-36)	Convergent	-1.50 (9.40)	0.18	N.S
	Divergent	-1.72 (9.33)		

learning by discovery to be relatively more difficult than learning from exposition. This result is not surprising because as initially hypothesised (Chapter 2, section 2.64) divergent thinkers who tend to look for alternative solutions to a problem should find discovery learning difficult as it requires critical analysis of information and selection of a specific hypothesis that fits all situations.

On the enjoyment/dislike scale, no discernable difference exists. Therefore, it seems that the leaning on convergency/divergency style has no bearing on the perception of the relative enjoyableness of the two modes of instruction.

7.3 SUMMARY AND CONCLUSIONS

In addition to the examination of the effect of cognitive styles on learning outcomes and behaviour in discovery and expository situations, the overall study also provided an opportunity for an examination of two "affective" aspects; students' perception of the relative difficulty and enjoyability of the two instructional modes, in relation to students' cognitive styles leaning.

To do so is both interesting and of importance because the success of any instructional approach cannot simply be assessed in terms of the learning that results from it, but must also address itself to the question of how students react to it.

a) In general, it was found that students in the overall sense find an expository teaching approach easier to cope with than an instructional approach based on discovery learning. This differentiation between the two modes of teaching is really very marked. For the second measure, the enjoyability of the two approaches, the finding is that students prefer the discovery technique over the exporatory technique, but the differentiation here is far less pronounced than for the ease/difficulty measure.

b) When it comes to an examination of the effect(s) of cognitive styles upon students' perception of the ease/difficulty or enjoyability of the two instructional modes, it is the differential effect of the cognitive styles that has to be examined. For this reason, the absolute ratings had to be replaced by the two relative measures defined in Section 7.2.

On the basis of these two measures, the following major findings were made:

i) Cognitive styles related differences on the relative ease/difficulty scale were found in relation to the conceptual differentiation style and the convergency/divergency measure. In each case, the direction of the difference appears to be in line with theoretical arguments.

ii) For the enjoyability scale, significant differences in the relative assessment of the two learning modes were found for the following cognitive styles: field dependence/field independence, the inferential conceptualisation style (ignoring the minor difference for the descriptive and relational styles for reasons already given). As in (i) the differences are explicable on theoretical grounds.

c) In the overall sense, the results show that the influence of cognitive styles is not confined to the cognitive outcomes from learning as such, but extend also to affective characteristics associated with learning. In general, the findings support some kind of "matching theory", whereby students' ratings of the relative ease/difficulty and enjoyableness of different modes of instruction seem to reflect the extent to which the learning requirements and conditions match the students' cognitive styles characteristics.

CHAPTER 8 GENERAL CONCLUSIONS AND EDUCATIONAL IMPLICATIONS

During the last thirty years or so, psychologists have identified major differences in the psychological functioning of individuals. The differences which often have the characters of genuine styles, relate to both cognitive and social behaviour of individuals. Not surprisingly, a good deal of interest has now developed among educationists in an exploration of these differences in the cognitive functioning of individuals, and especially of the effect of different cognitive styles on learning and instruction. The present study was conceived in this spirit and represents an attempt to examine the influence of a few selected cognitive styles on students' learning behaviour in the context of two different instructional modes (discovery/expository).

Initially in the study reported in this thesis, a theoretical analysis of the ways in which the differential leanings of individuals on the different cognitive styles should affect their learning from different modes of instruction was carried out. As part of this, various cognitive styles were examined and their characteristics conceptualised. This proved to be a challenging task for the simple reason that the relationship between the activities involved in the assessment of the cognitive style and the underlying cognitive processes are not readily apparent. Hence, the characteristics suggested and formulated for some of the cognitive style are bound to be speculative and tentative in nature. Thereafter, in order to link the individual differences in cognitive styles to learning behaviour a simple learning model was employed which depicts the learning process as comprising four basic processes; information perception, information selection/organisation, information transformation, and information storage. An attempt was then made to "match" the characteristics associated with each of the cognitive styles with the "events" of the different stages of learning model mentioned above. From the range of cognitive styles, a group of five styles was selected for closer investigation in the study. The styles chosen were:

i) Field independence/field dependence

ii) Conceptualisation styles

iii) Conceptual differentiation

iv) Convergency-divergency

v) Reflectivity-impulsivity

The investigation was carried out in two phases. In Phase I of the study an examination was made of the effects of the first four cognitive styles listed above on learning from a set of five short learning exercises. Each exercise was presented in two formats, one corresponding to the discovery mode of instruction, the other corresponding to the expository teaching mode. Phase II of the study involved a further examination of the effects of cognitive style on learning but this time with respect to a set of chemistry learning tasks. Based on the data reported in Chapters 5 and 6, several observations and conclusions can be made concerning the relationship between cognitive styles and learning behaviour.

a) The field independence/field dependence cognitive style has a significant influence on learning outcome, irrespective of the instructional mode used (discovery or expository). Field independent persons perform better in both discovery learning and learning from exposition. This superiority may be explained in terms of the strong orientation of field independent persons towards analytical thinking, compared with field dependent persons. This is further supported by the finding that the significant difference between the performance levels of field independent and of field dependent subjects is still observed even after partialling out the IQ effects.

b) In relation to the conceptualisation styles (inferential, descriptive and relational), only the inferential style seems to have a direct significant influence on students' learning in discovery situations (the expository mode was omitted from the examination). A likely explanation for this is that inferential thinkers have a comparative high leaning towards an analytic-cum-synthetic treatment of information which places them at an advantage in processes which involve, the selection and organisation of information for the purpose of formulating rules, as is required in discovery situations.

c) As far as the conceptual differentiation style is concerned, no consistent trends were observed to relate learning behaviour to students' leaning towards conceptual differentiation. Conceptual differentiation involve the subdivision of a group of stimuli into smaller groups, and so represents an activity from which a process of synthesis of information for the purpose of concept formulation is missing. The reason why no relationship was found between conceptual differentiation and learning in the present study, may well have been that most of the learning tasks required some synthesis of information to formulate concepts or rules. In general, in the light of the present findings, it must be doubtful whether conceptual differentiation should have any major significant influence on learning.

d) The results in relation to the convergency-divergency style are not sufficiently consistent to allow a firm conclusion to be drawn. In the case of two learning tasks (Scrambled Words tasks and the Unit 3 Chemistry task), the difference in performance were found which are statistically significant and support the initial hypothesis that convergent thinkers should do better than divergent thinkers in discovery situations. Other learning tasks however gave no support for this hypothesis, but this may have been due to the nature of the learning tasks used in the study. The tasks were not specifically designed to match the cognitive characteristics of the convergency-divergency style. Perhaps if more appropriate tasks which allow alternative solutions to be produced were used, the leaning of learners towards the opposite poles of the convergency-divergency construct might have been found to have a significant bearing on learning outcomes.

e) In relation to the reflectivity-impulsivity style, the results of the present study do not support the hypothesis that reflective individuals should have an advantage over impulsive individuals, in learning, especially by the discovery approach. Once again, the problem seems to be the nature of the learning tasks. The learning tasks did not give rise to many response alternatives simultaneously as in the Matching Familiar Test. The Matching Familiar Test appears mainly to be a perceptual task whilst the chemistry learning activities in the present study were concerned with the selection, organisation and abstraction of generalisation. As such the reflective/impulsive character of the learner which was conceptualised to have a significant bearing on the information selection stage of learning does not appear to play a significant part in concept formulation tasks. Perhaps in learning situations where information perception and selection play an important role for success as in practical chemistry tasks, the reflective/impulsive character of the learner would have a significant influence on achievement.

One of the shortcomings of the present study, as has to be admitted with hindsight, was the use of a single set of learning tasks to examine the influence of different cognitive styles with varying cognitive characteristics on learning behaviour. Further studies should use specially designed learning tasks to match the characteristics of each of the cognitive styles, and this might produce a clearer insight into the specific influences of cognitive styles on learning behaviour in instructional approaches.

The practical significance of this study lies in its potential for suggesting ways by which educators can apply knowledge of individual differences in cognitive styles in the design of learning material in such a manner so as to enhance students' learning outcome. The results from data analysis and close examination of the interaction support the general notion that certain cognitive styles do have a significant influence on learning. In the present study, this was clearly established for the field independence/dependence cognitive style and for the inferential conceptualisation style. The ability to abstract particular elements from a random array of information and impose structure (which is a characteristic associated with field independence) evidently gives field independent individuals an advantage over field dependent persons in learning situations which require the learners to handle information on their own. The same appears to be the case in relation to inferential conceptualisation style. The analytic-synthetic thinking behaviour of high inferential thinkers appears to help them in concept and/or rule formulation tasks as they arise especially in discovery learning. By the same arguments, it follows that an extensive reliance on discovery learning could pose a problem for some students. Therefore, the evidence from this investigation suggests that cognitive styles as learner characteristics should receive more attention if educators are concerned with (i) how students learn and (ii) how the particular cognitive processing and psychological behaviour associated with each of the cognitive styles can best be engaged in learning/teaching the skills and concepts contained in any curriculum. However, it must be recognised that cognitive styles represent only one in a multitude of factors affecting students' learning in a classroom situation. Nevertheless, it is specific interaction areas such as those identified in this study that can be useful in the design of learning situations.

One of the limitation of the present study lies in the fact that only immediate retention variables were used as the criterion measures of learning. Further studies that include long term retention and also transfer of learning criterion would help to throw more light on the influence of cognitive styles on learning and instruction.

Besides the influence on learning behaviour it was hypothesised that cognitive styles would also affect students' perception of instructional approaches, and for this reason students' views of the ease/difficulty and the enjoyableness of learning by discovery and learning from exposition were examined as part of the Phase I study. The results on the whole indicate that some significant relationship exists between cognitive styles leaning and preference for a learning type.

i) Differences on the relative ease/difficulty scale were found in relation to the conceptual differentiation style and the convergency/divergency measure. High conceptual differentiators and divergent thinkers perceived learning by discovery to be more difficult than learning from exposition.

ii) For the enjoyability scale, significant differences in the relative assessment of the two learning modes were found for the following cognitive styles: field independence/field dependence and the inferential conceptualisation style. Field independent subjects and high inferential thinkers perceived learning by discovery to be more enjoyable than learning from exposition.

In the overall sense, the results show that the influence of cognitive styles is not confined to the cognitive outcomes from learning as such but extend also to affective characteristics associated with learning. This suggests that the concept of attitude-aptitude-interaction should be included in cognitive styles research because students' attitude towards an instructional strategy may prove to be no less important for their learning than their aptitude. The present study indicates to some extent that a relationship exists between learning outcome and students' perception of an instructional mode. Therefore, it appears to be a line of research worth pursuing. This is particularly important in relation to discovery learning because of the great emphasis given to discovery learning in modern science and mathematics curricula, irrespective of the learners' aptitude, cognitive characteristics and attitude towards this mode of learning.

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APPENDICES

APPENDIX A.1

THE CONCEALED SHAPES TEST

THE CONCEALED SHAPES TEST.

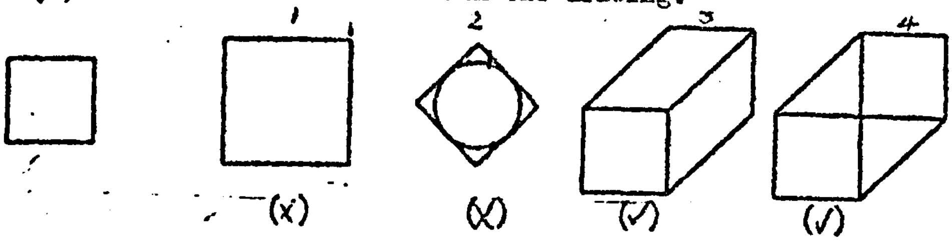
NAME.................................... AGE.........years.........months.

SCHOOL...

YOUR TEACHER WILL READ THIS WITH YOU.

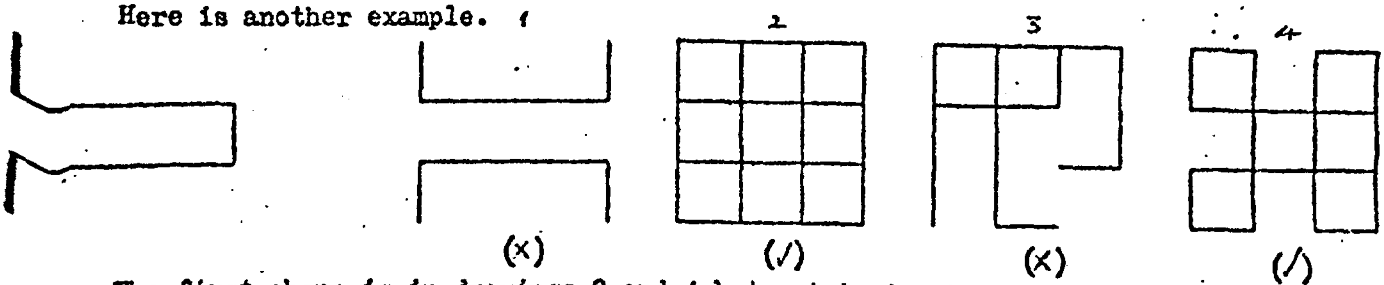
THIS IS A TEST TO DO WITH SHAPES. LOOK AT THE FIRST LINE BELOW.

Your job is to decide whether the first drawing in the line is hidden in each of the other four drawings. <u>It must be the same size and the same way round.</u> If it <u>is</u> put a tick (✓) in the brackets underneath the drawing: if it is <u>not</u> put a cross (X) in the brackets underneath the drawing.



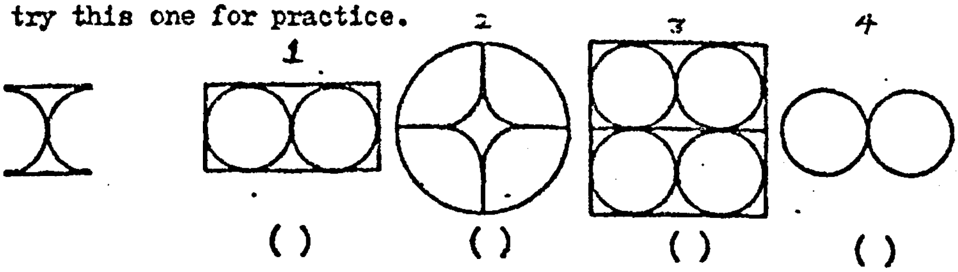
In this line of shapes you can see that the square is in drawing numbered 3 and in number 4, so that a tick has been placed in the brackets underneath. Though drawing 1 is a square it is too big, so a cross has been put in the brackets. Though there is a square of the same size in drawing 2 it has been turned around, so a cross has been put in the bracket below.

Here is another example.



The first shape is in drawings 2 and 4 but not in drawings 1 and 3.

Now try this one for practice.



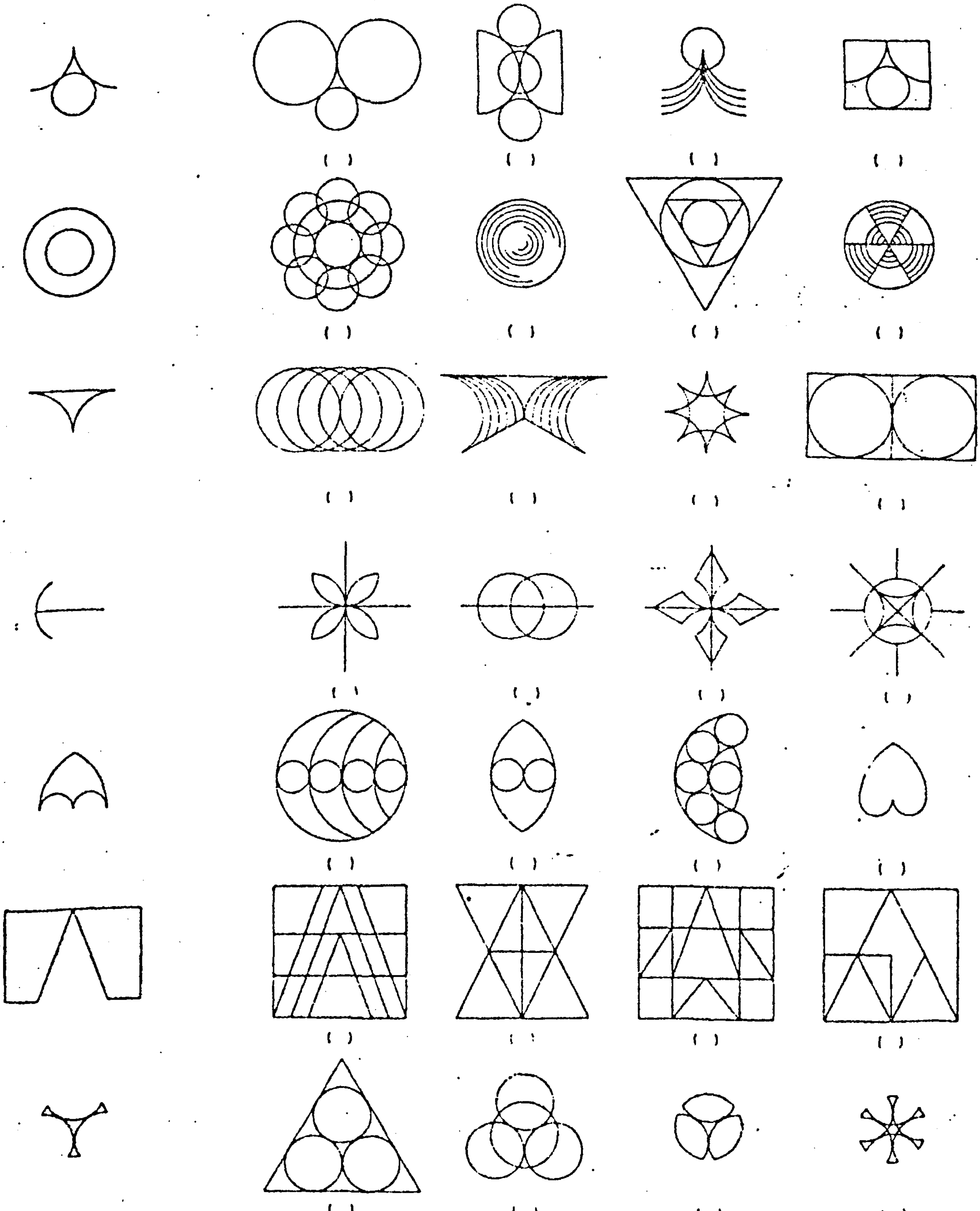
You should have marked drawings 1 and 3 with a tick (✓) and drawings 2 and 4 with a cross (X).

ALL THE TEST IS DONE EXACTLY LIKE THAT. THE SHAPE IS HIDDEN IN AT LEAST ONE DRAWING AND MAY BE IN AS MANY AS ALL FOUR.

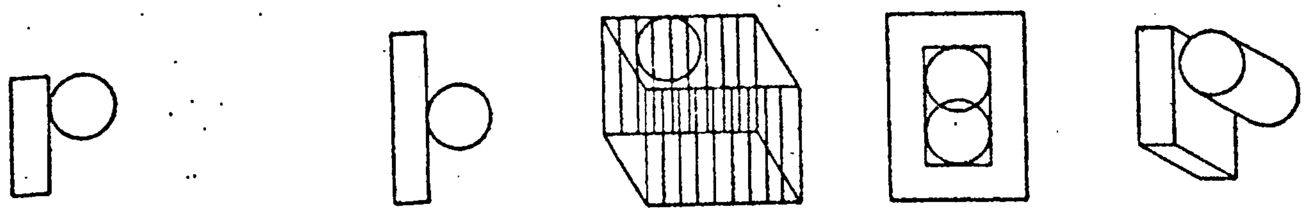
DO NOT START UNTIL YOU ARE TOLD.

YOU WILL ONLY HAVE A SHORT TIME FOR THE TEST SO WORK AS QUICKLY AS YOU CAN.

<u>WAIT FOR THE SIGNAL TO BEGIN.</u>



DO NOT STOP. GO ON TO THE NEXT PAGE.



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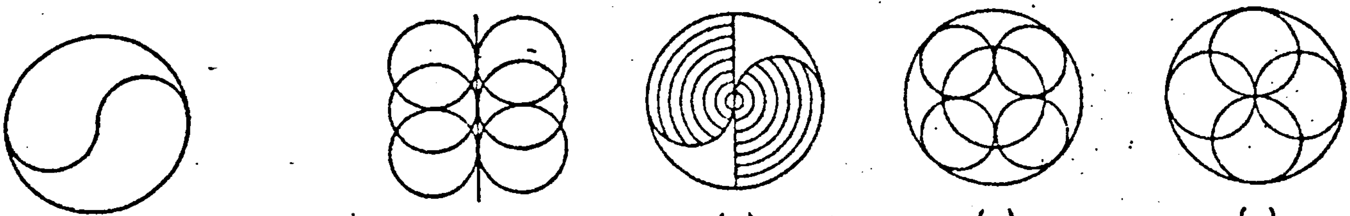

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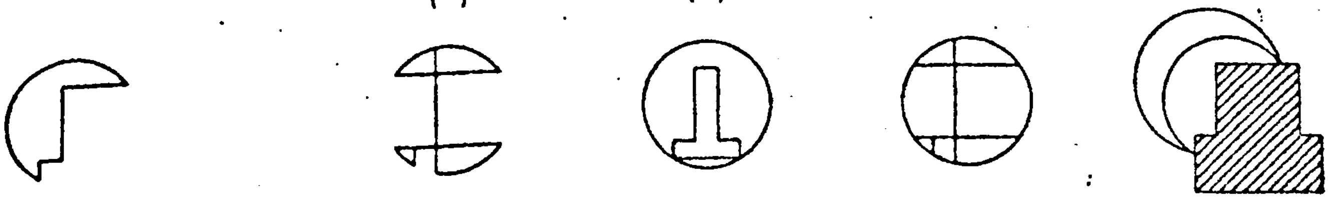

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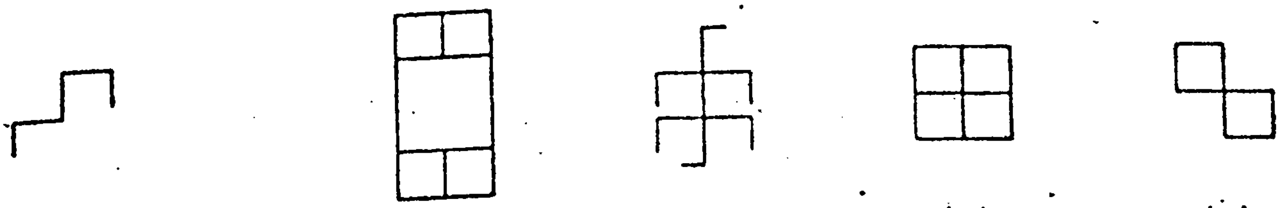

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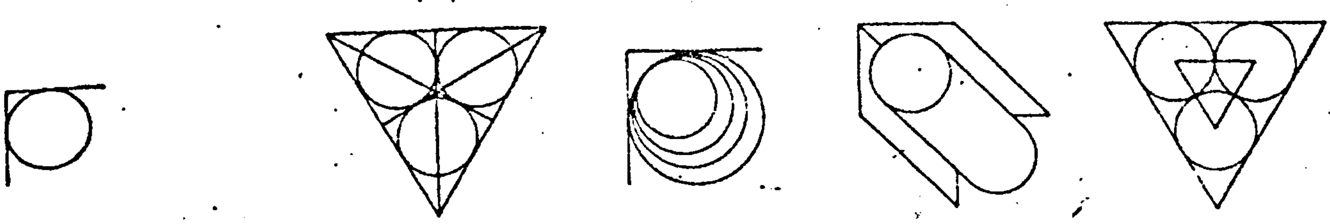

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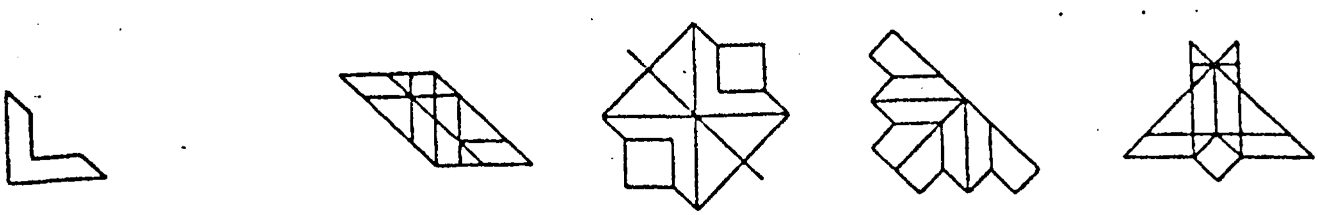

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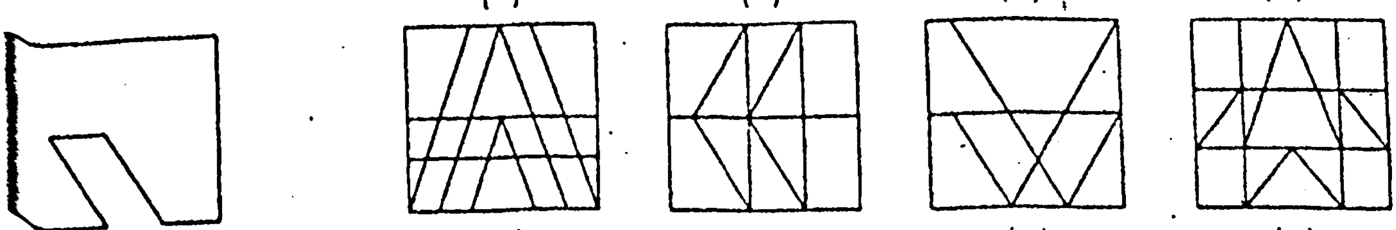

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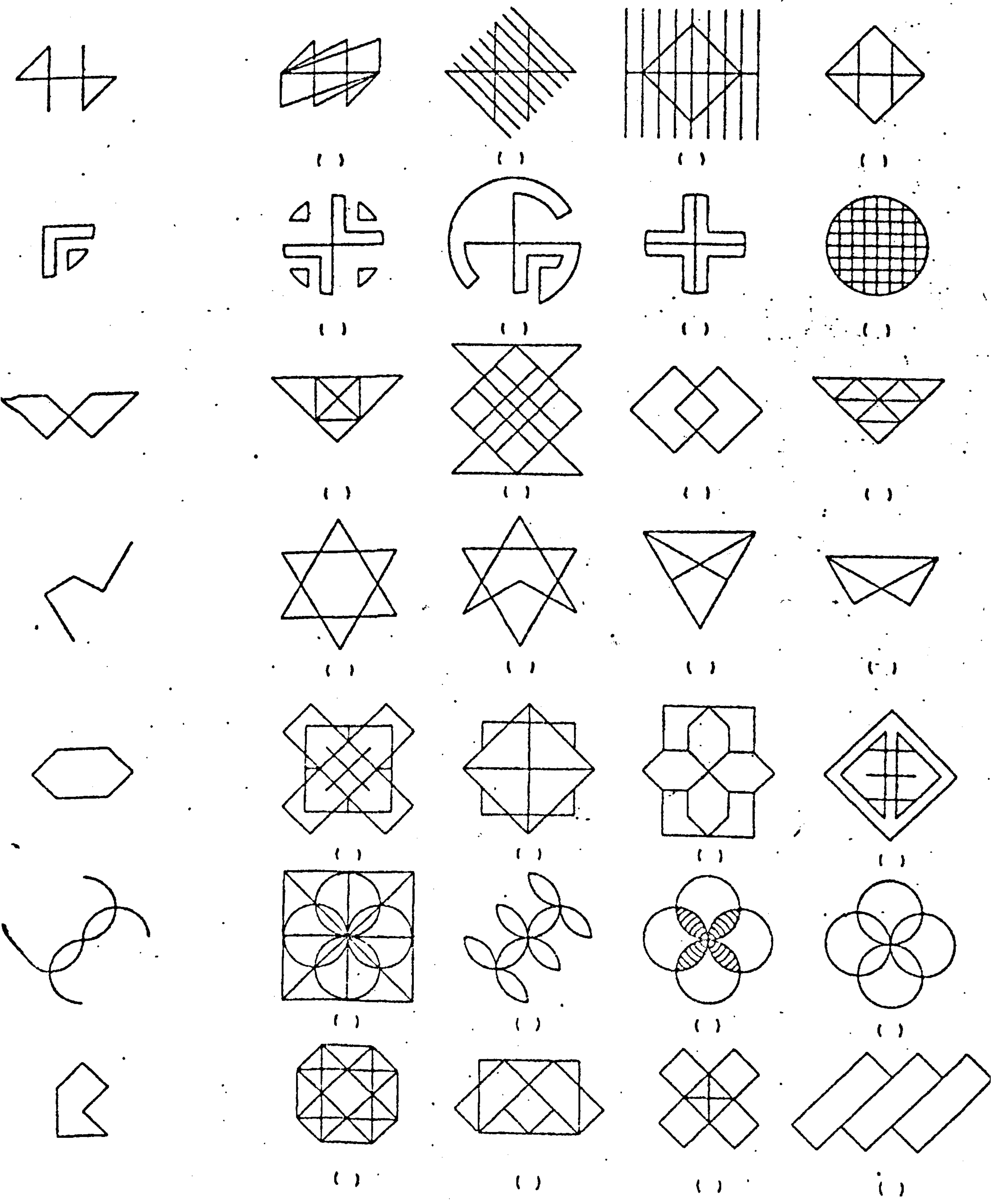
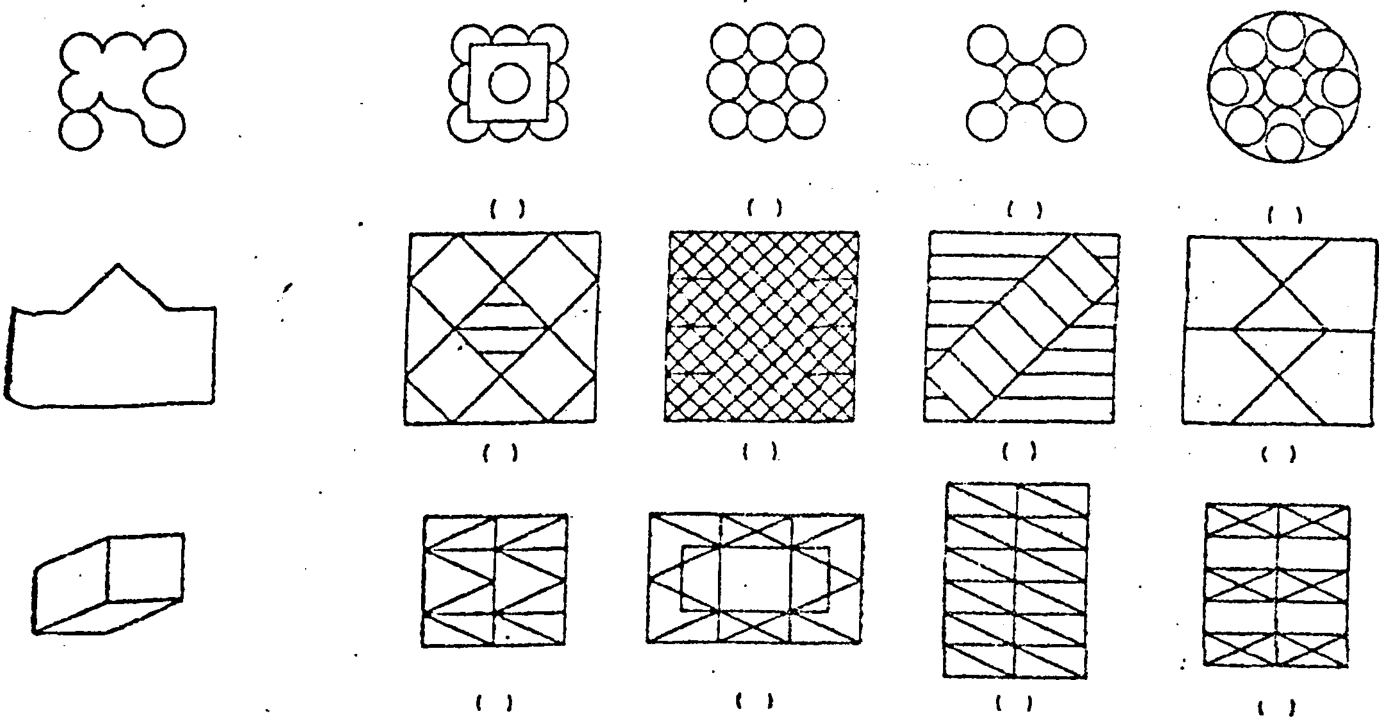
DO NOT STOP. GO ON TO THE NEXT PAGE.



DO NOT STOP. GO ON TO THE NEXT PAGE.



STOP HERE -- WAIT FOR FURTHER INSTRUCTIONS.

APPENDIX A.2

HIDDEN FIGURES TEST

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DEPARTMENT OF EDUCATION

HIDDEN FIGURES TEST

This is a test of your ability to find a simple form when it is hidden wit in a complex figure.

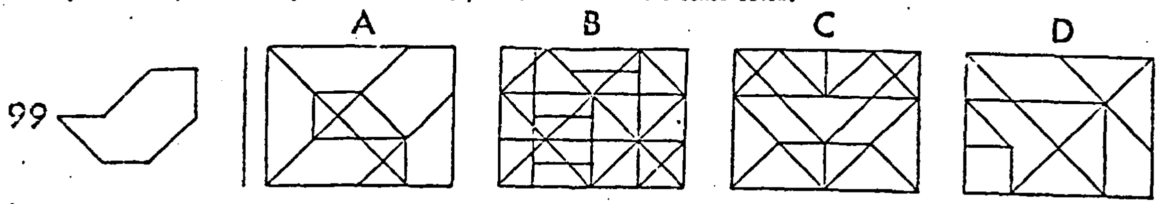
Each item within this test consists of a simple form on the left followed by four complex figures on the right, labelled A, B, C, D. You should carefully examine each of these complex figures to find out whether or not the simple form is hidden within it. Then mark the box on your answer sheet accordingly. Record your answers as follows:

Put X in the appropriate box if the simple form is hidden in the complex figure.
Put O in the appropriate box if the simple form is NOT hidden in the complex figure.

If you are uncertain about whether or not a complex figure contains the simple form, do not mark the appropriate box.

Note: The hidden form will always be the SAME SIZE and the SAME WAY ROUND as it is shown in the left hand column. It may appear in more than one of the four complex figures or in none of them.

Now try this example. When you have decided, put 'X' or 'O' in the boxes below.



Answer

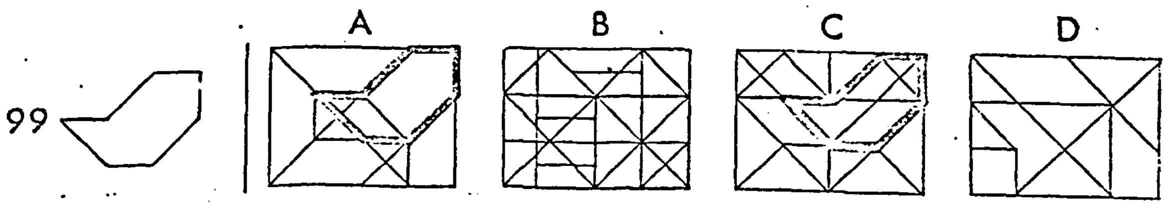
	A	B	C	D
99.				

When you have done this, turn the page to check your solution.

The correct answer is:

	A	B	C	D
99.	X	O	X	O

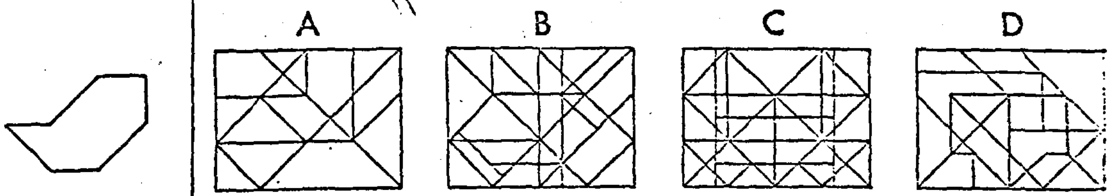
To show you the answer, the simple form has been traced over the lines of the complex figures within which it is hidden.

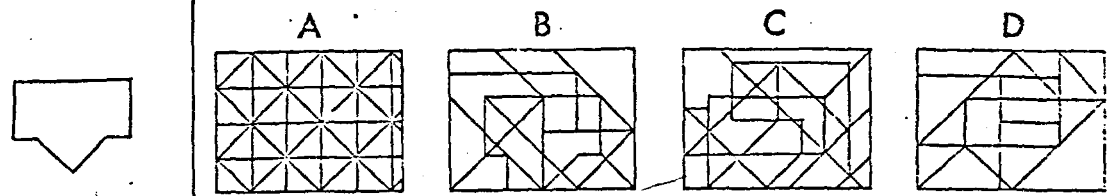


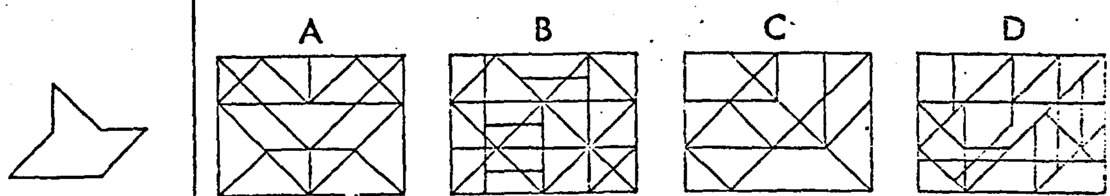
Work through the items quickly but carefully. It is advisable to work in pencil with a rubber available so that if you change your mind after you have marked your answer you can easily alter it. There are twelve items in the test and you have twelve minutes in which to do them.

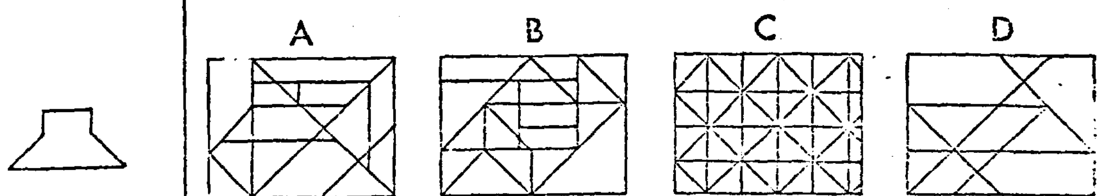
REMEMBER the hidden form will always be the SAME SIZE and the SAME WAY ROUND as it is shown in the left hand column.

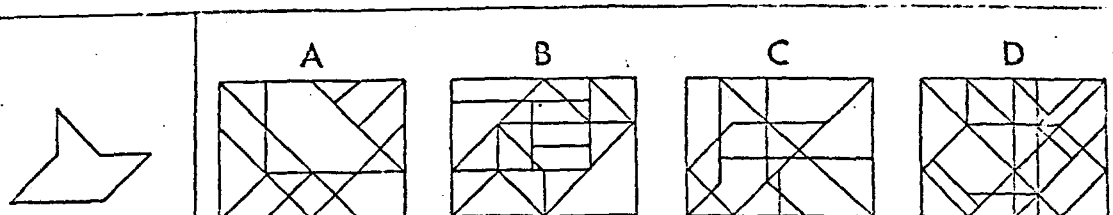
DO NOT TURN OVER UNTIL YOU ARE TOLD TO DO SO.

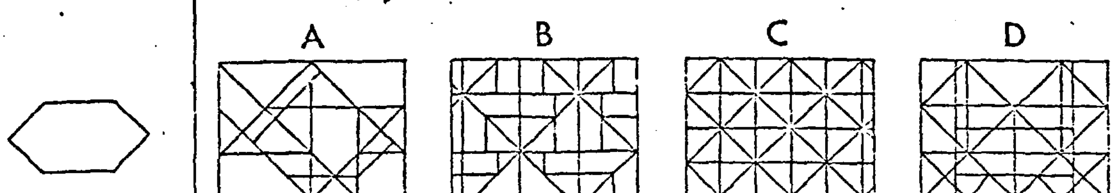
1


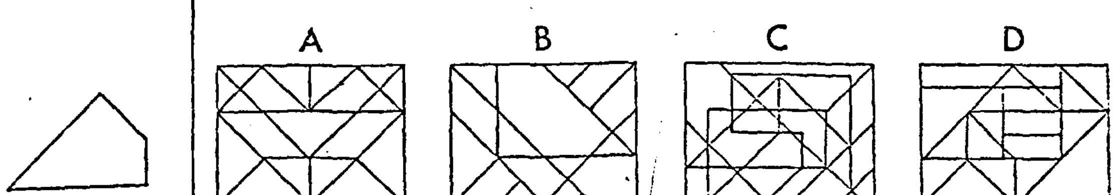
2


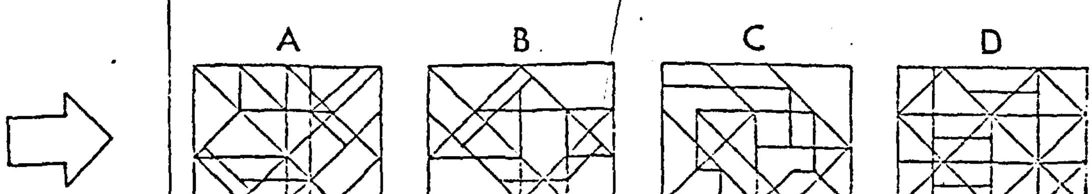
3


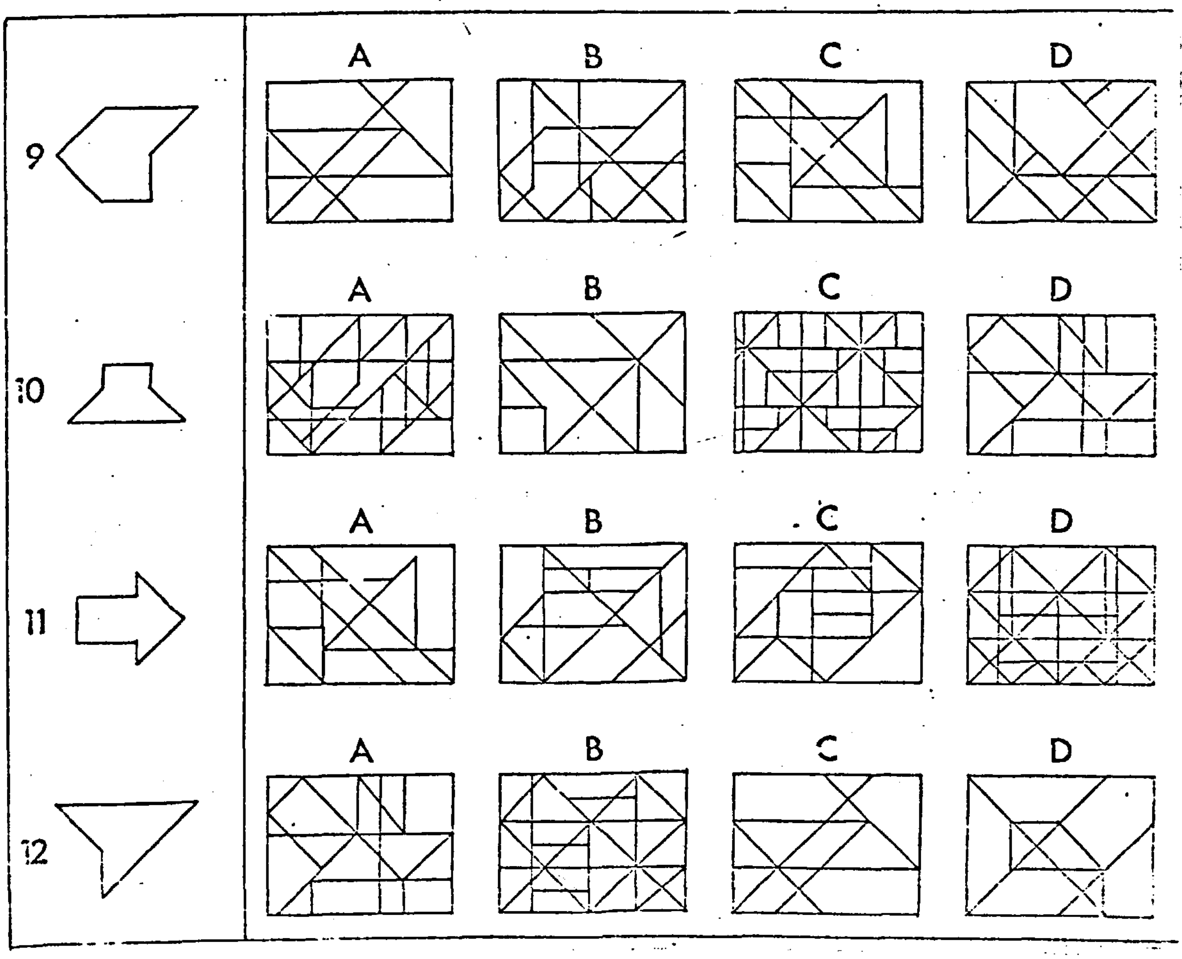
4


5


6


7


8




9
10
11
12
A
B
C
D

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Department of Education

Hidden Figures Test

NAME ______________________ FORM __________

SCHOOL ______________________ DATE __________

Directions: Put **X** in the appropriate box if the simple form is hidden in the complex figure.

Put **O** in the appropriate box if the simple form is NOT hidden in the complex figure.

Item	A	B	C	D
1	☐	☐	☐	☐
2	☐	☐	☐	☐
3	☐	☐	☐	☐
4	☐	☐	☐	☐
5	☐	☐	☐	☐
6	☐	☐	☐	☐
7	☐	☐	☐	☐
8	☐	☐	☐	☐
9	☐	☐	☐	☐
10	☐	☐	☐	☐
11	☐	☐	☐	☐
12	☐	☐	☐	☐

APPENDIX A.3

CONCEPTUAL PREFERENCE TEST

UNIVERSITY OF KEELE

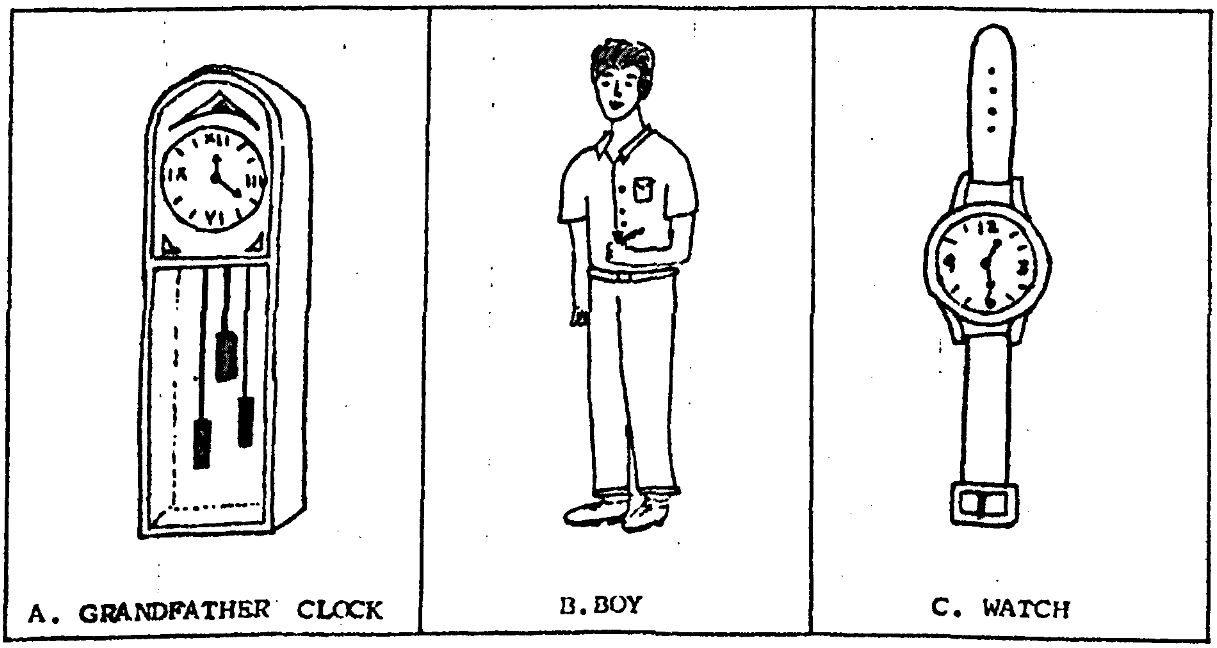
Department of Education

CONCEPTUAL PREFERENCE INVENTORY

This is an exercise designed to find out something about the way you think and the way you see things. There are no right and wrong answers in this exercise.

The exercise consists of 24 items. Each item contains three pictures of familiar things and three statements about them. Each of the statements links two of the pictures in the item. Read carefully each of the statements and decide how well you think it describes how the two pictures go together. Select your most preferred and your least preferred statement. Enter your choices in the answer sheet provided.

Now look at this example.



Item.

99 a) A and C are time measuring devices.

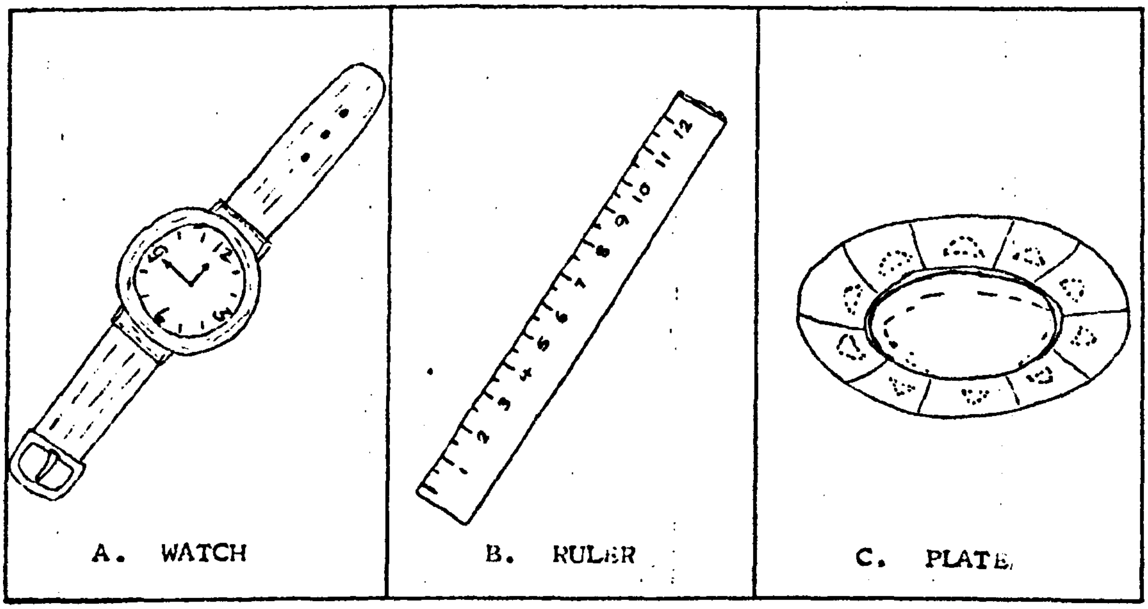
b) B can wear C on his hand.

c) A and C have dials on them.

Response.	MOST PREFERRED	LEAST PREFERRED
99	a	c

A person answering this item in the manner shown would have felt that statement (a) was the best description of how the two selected pictures go together and statement (c) was the poorest description of how the two selected pictures go together. You may have responded in a different way.

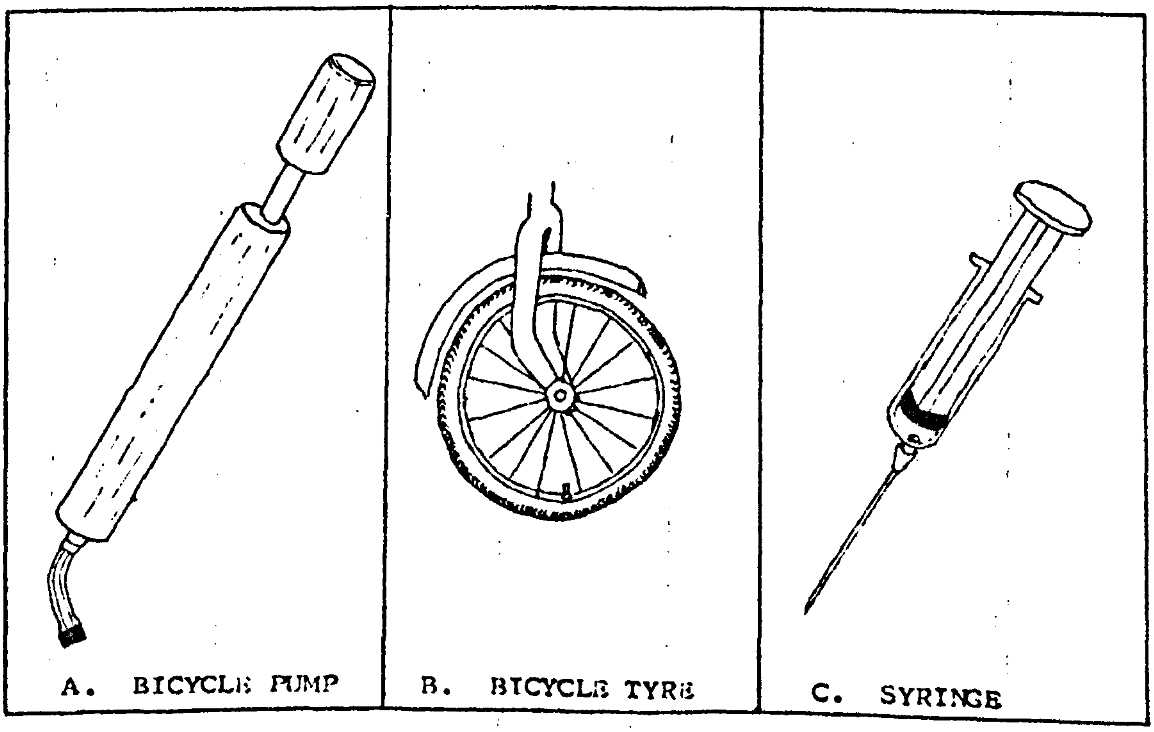
IF YOU ARE READY TURN OVER THE PAGE AND WORK THROUGH THE EXERCISE.



1. a) A and B are measuring instruments.

   b) A and C have circular shape.

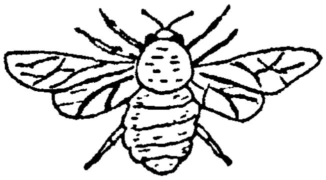
   c) B can be used to measure the diameter of C.



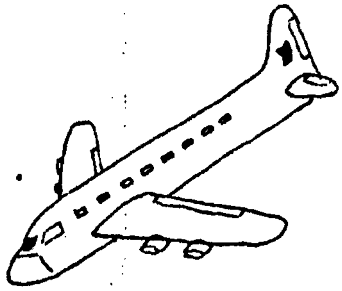
2. a) A can be used to inflate B.

   b) A and C are straight and cylindrical.

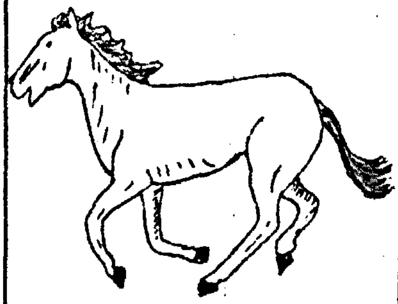
   c) A and C are piston action devices.



A. WASP



B. AEROPLANE

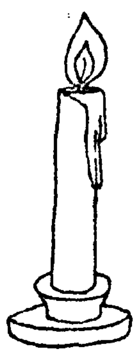


C. HORSE

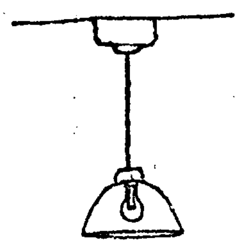
3. a) B and C are means of transport.

   b) A can frighten C.

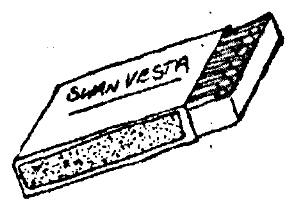
   c) A and B have wings.



A. CANDLE



B. ELECTRIC LIGHT

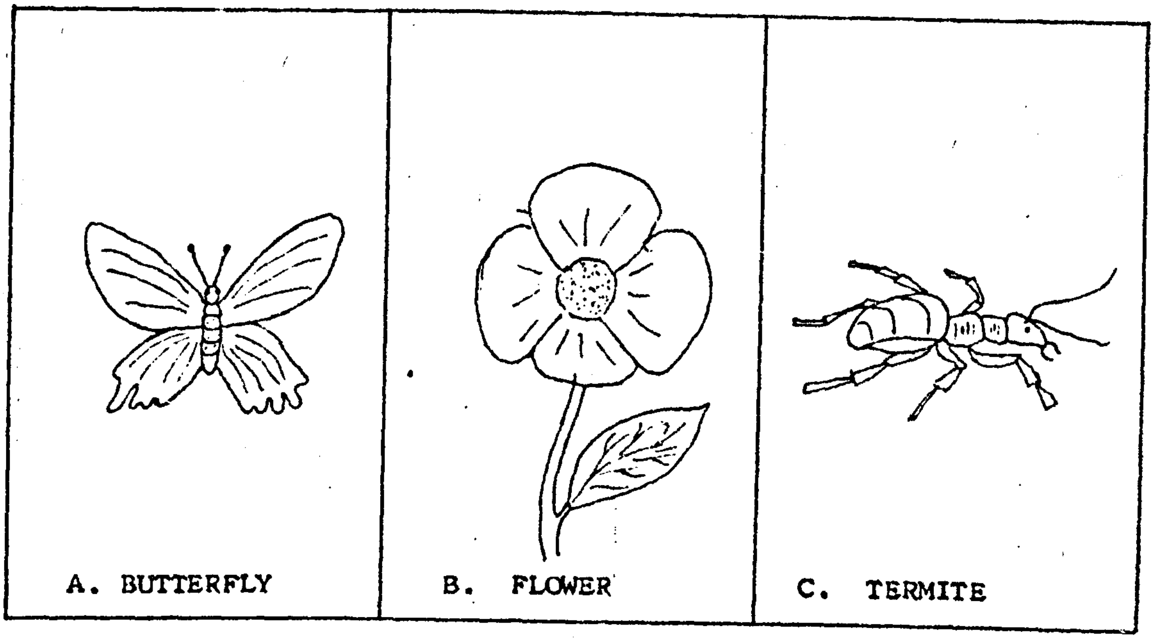


C. MATCHES

4. a) C can be used to light A.

   b) A and B are sources of light.

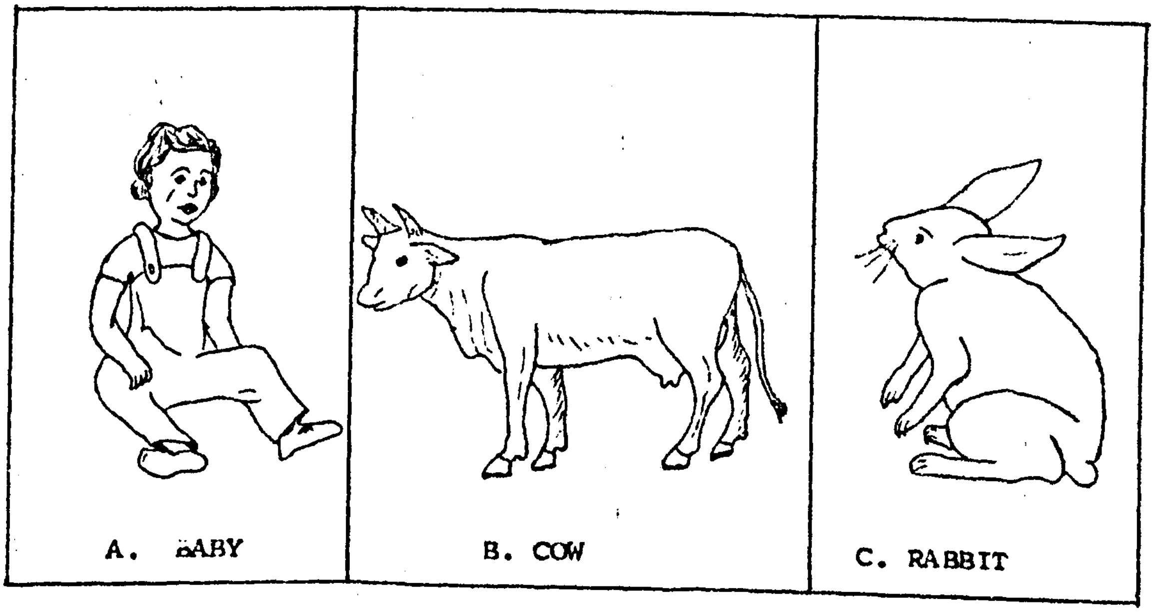
   c) A and C have straight edges.



5. a) A and C have segmented body.

b) A can get nectar from B.

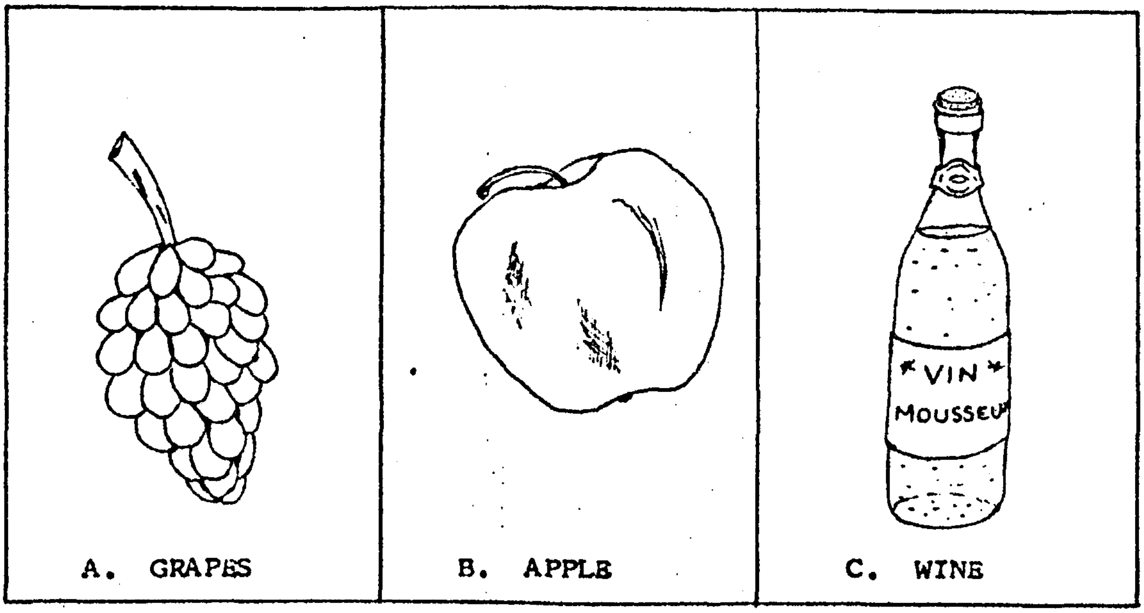
c) A and C are insects.



6. a) A and C are sitting.

b) A can drink the milk from B.

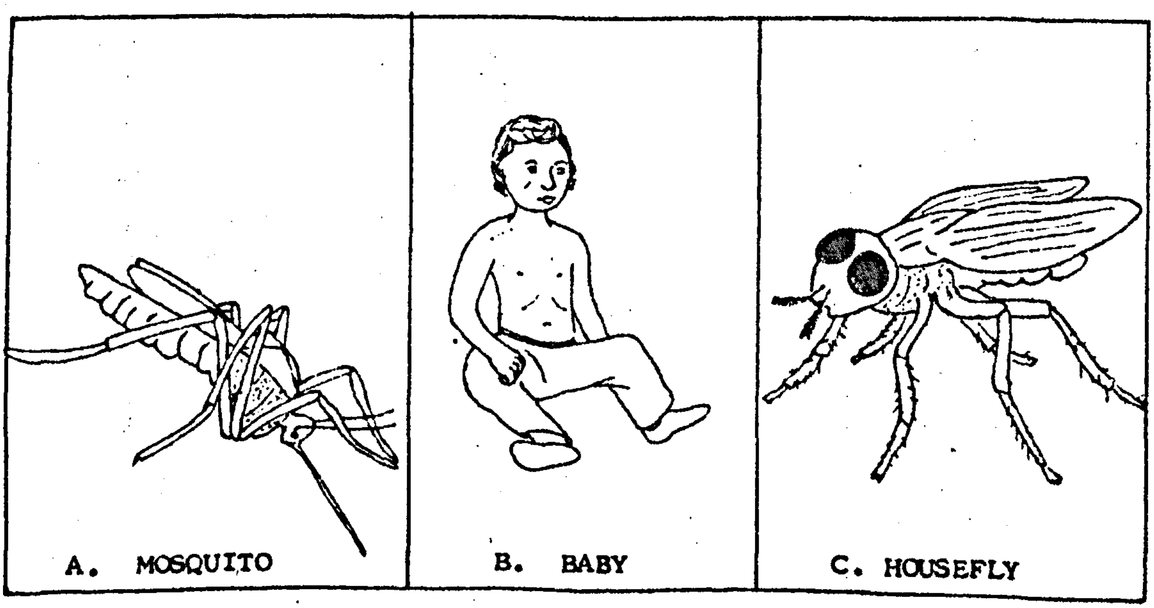
c) B and C are grass-eating animals.



7. a) A and B have smooth skin.

   b) C is made from A.

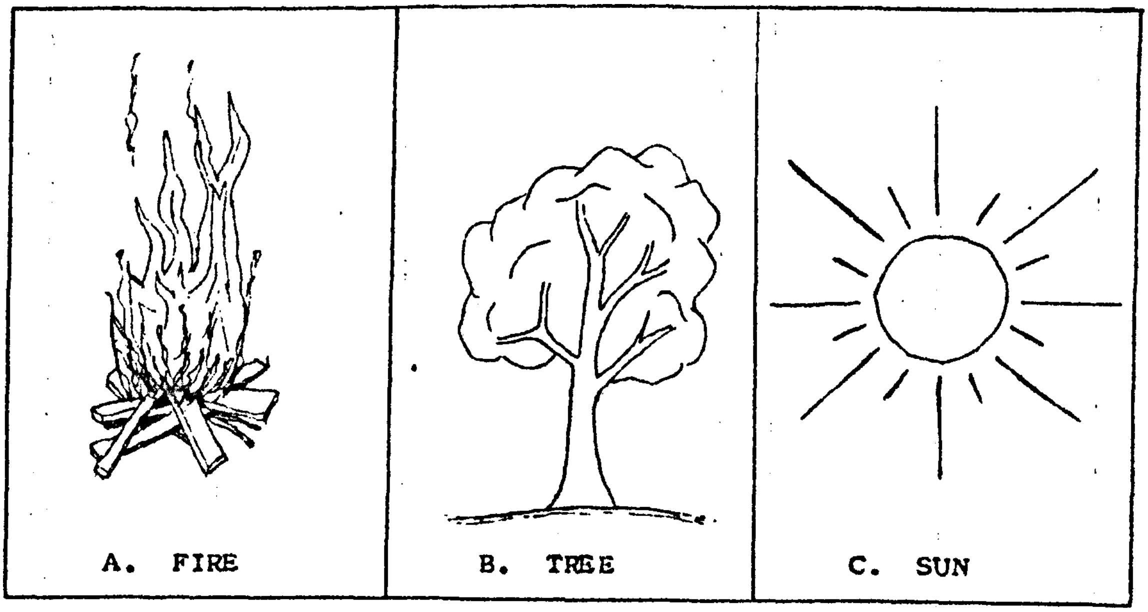
   c) A and B are fruits.



8. a) A and C are disease-carrying insects.

   b) A can bite B.

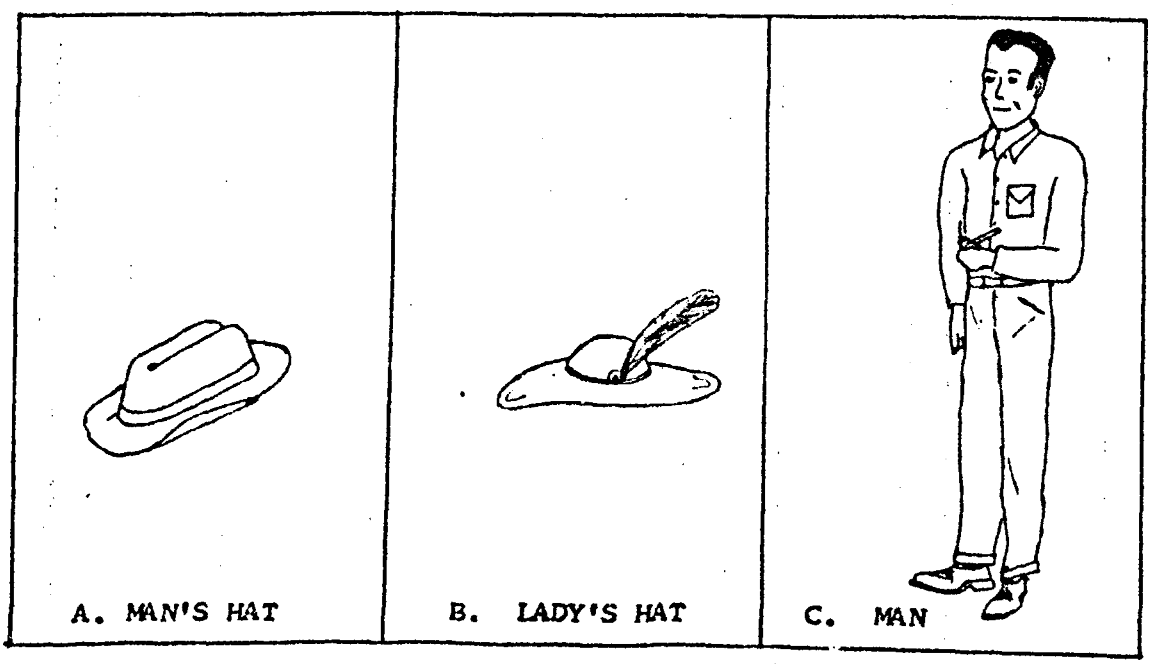
   c) A and C, both have six legs.



9. a) A and C give out light.

b) B gets energy from C.

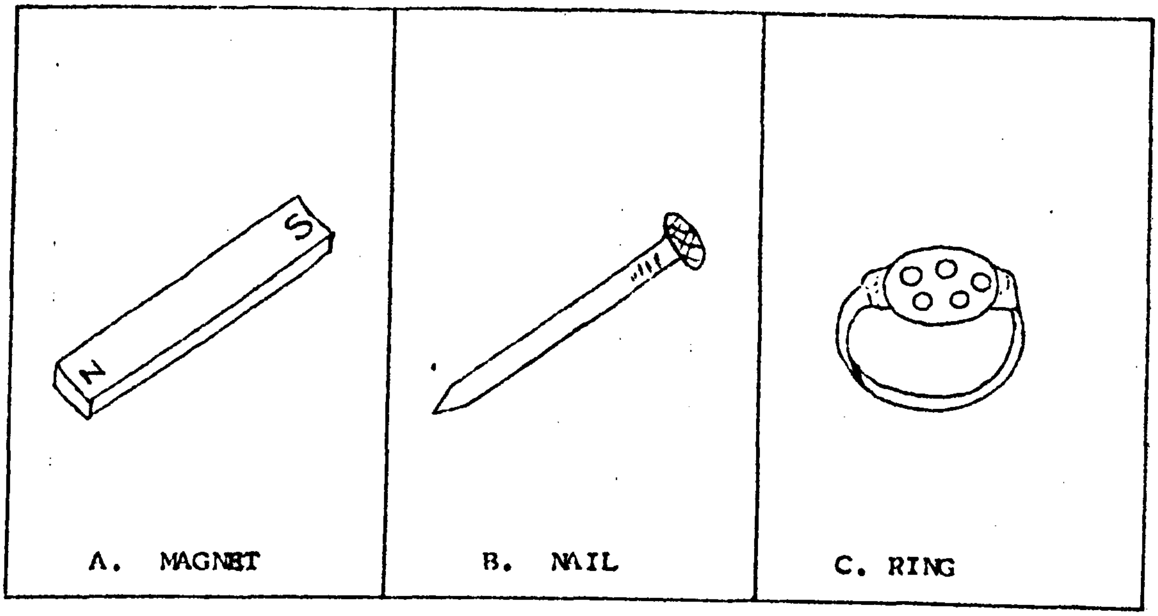
c) A and C are sources of warmth.



10. a) A and B are head wears.

b) C can wear A.

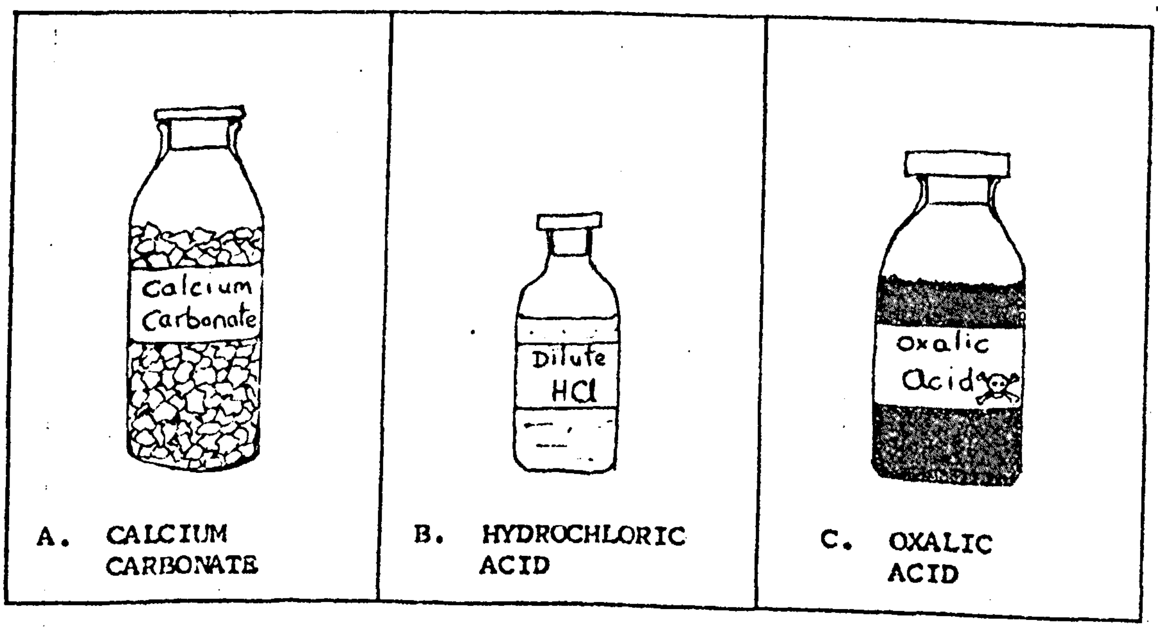
c) A and B have round surface.



11. a) A can attract B.

b) B and C have circular part.

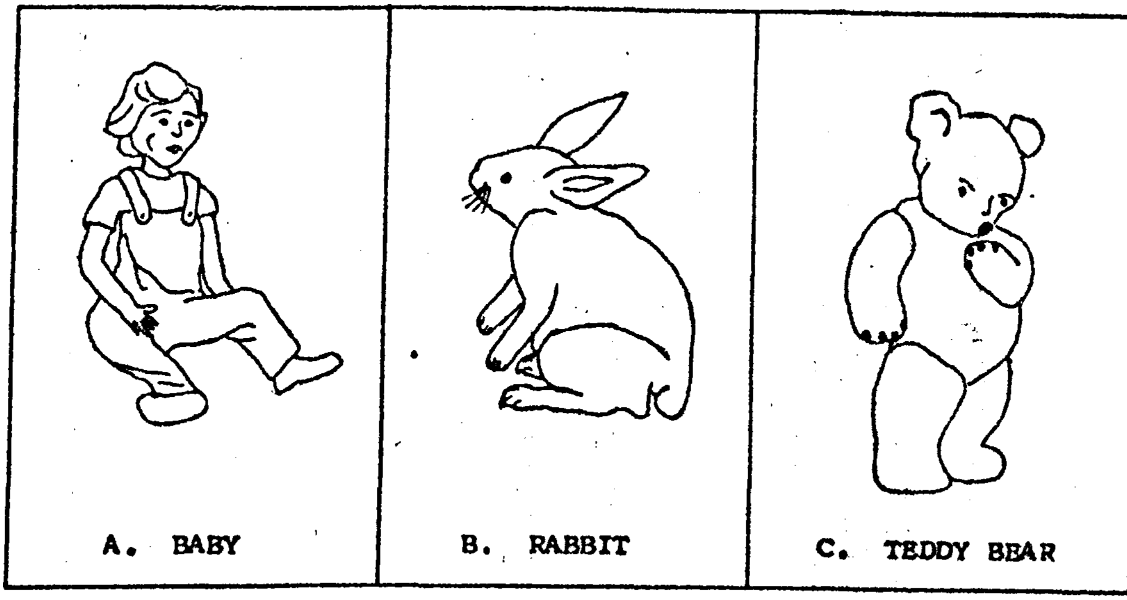
c) A and B are straight objects.



12. a) A and B are contained in large flasks.

b) A can react with B.

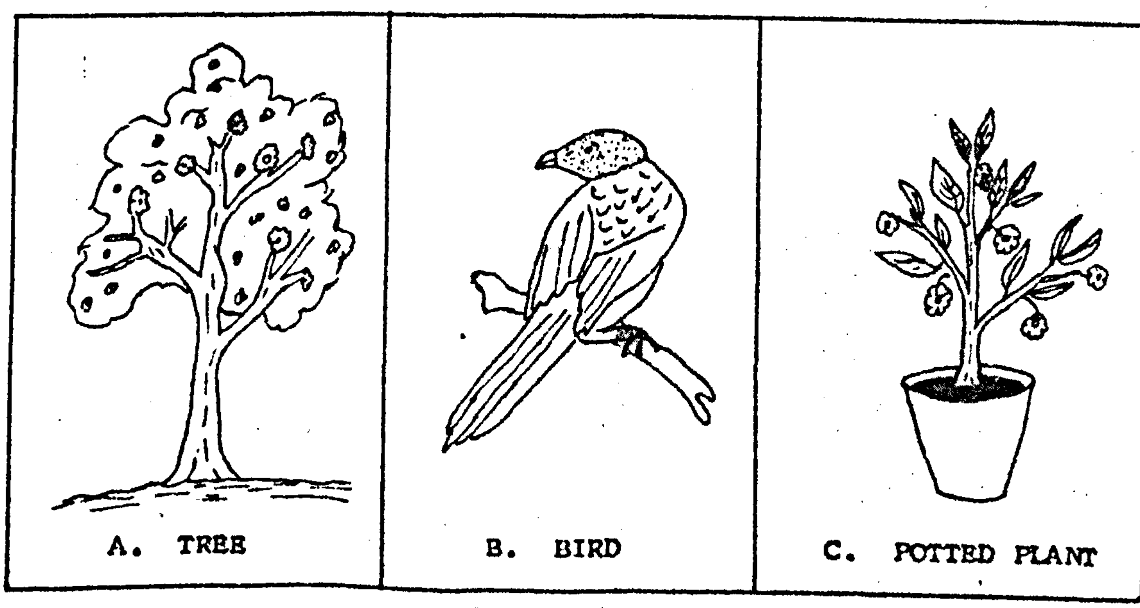
c) B and C are acids.



13. a) A can play with C.

    b) A and B are living things.

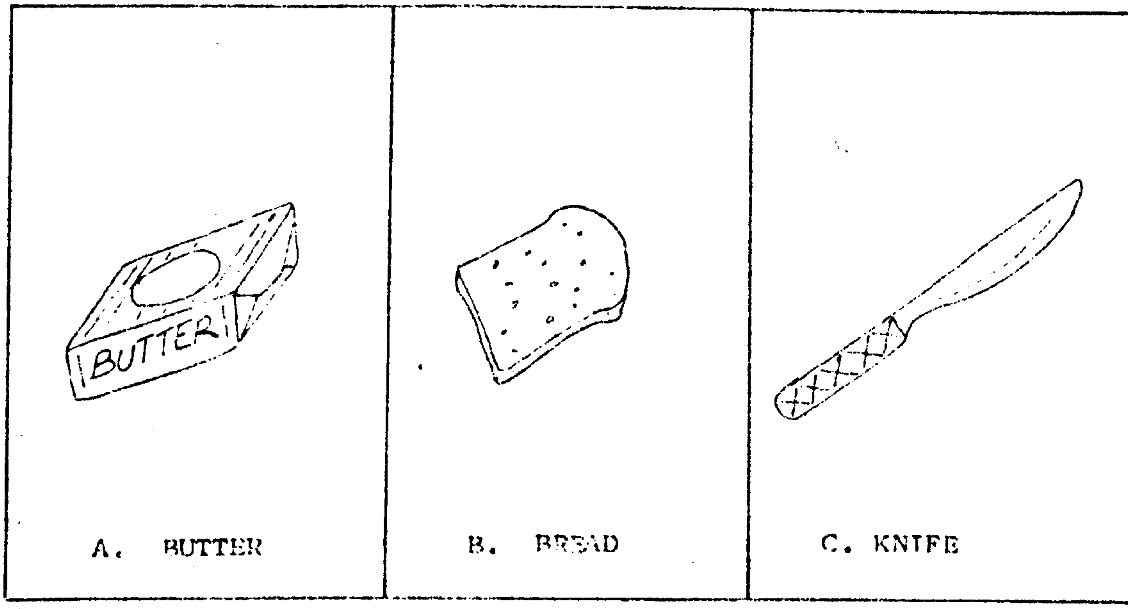
    c) B and C are furry.



14. a) A and C are flowering plants.

    b) B can build its nest on A.

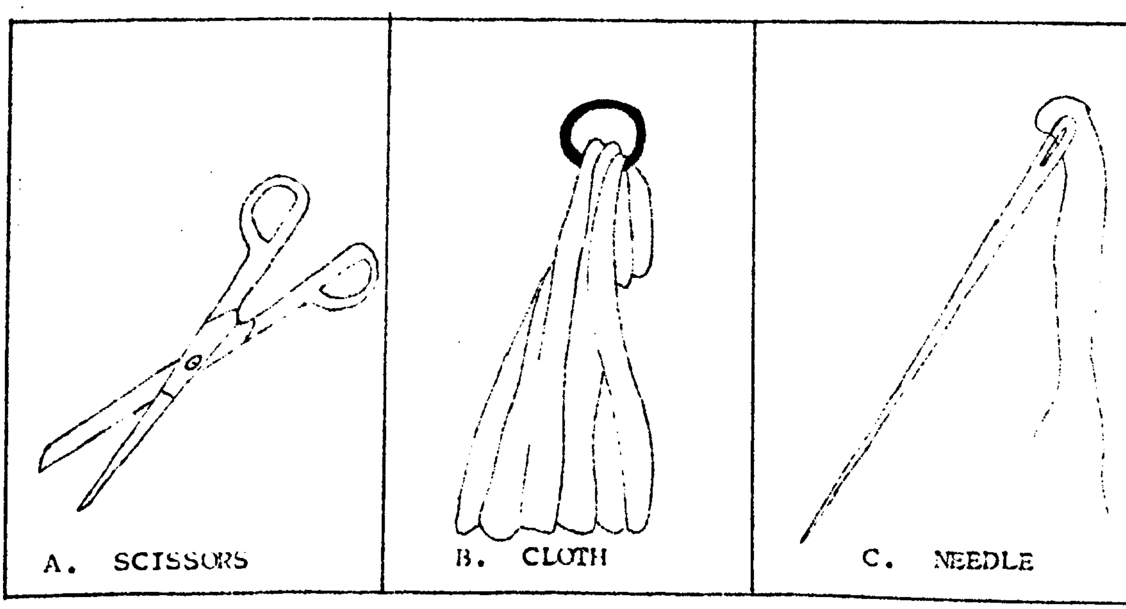
    c) A and C have branches.



15. a) A and B are food-stuffs.

b) C can be used to spread A.

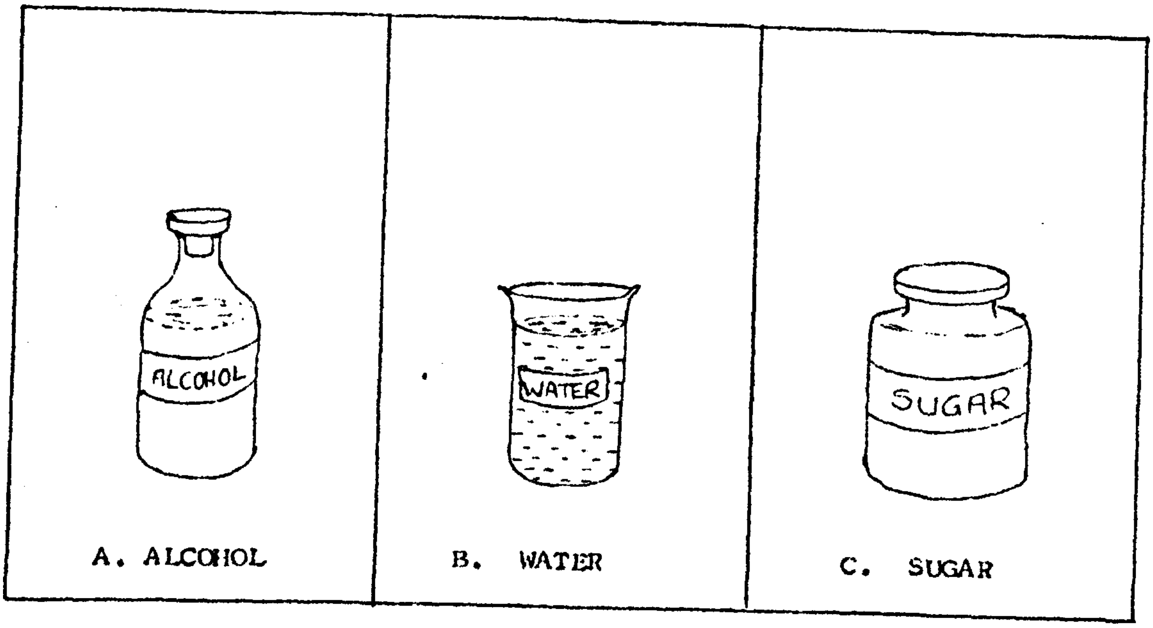
c) A and B are soft.



16. a) A and C are made of metal.

b) A can be used to cut B.

c) A and C are sewing aids.

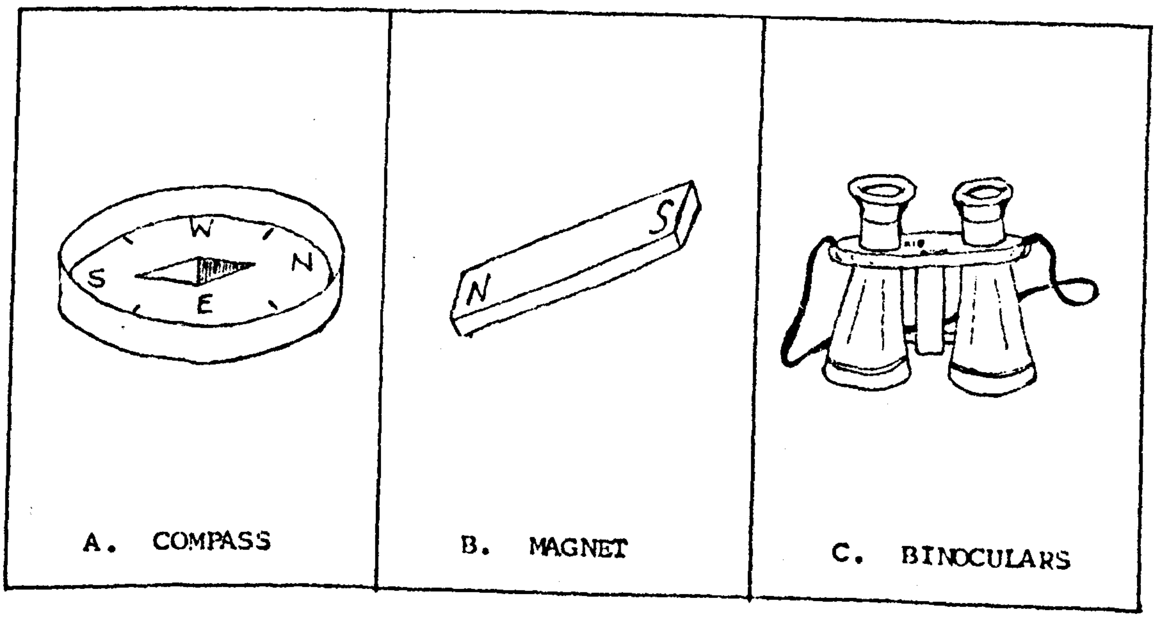


A. ALCOHOL B. WATER C. SUGAR

17. a) A and B are in the liquid state.

b) C can dissolve in B.

c) A and B are organic substances.

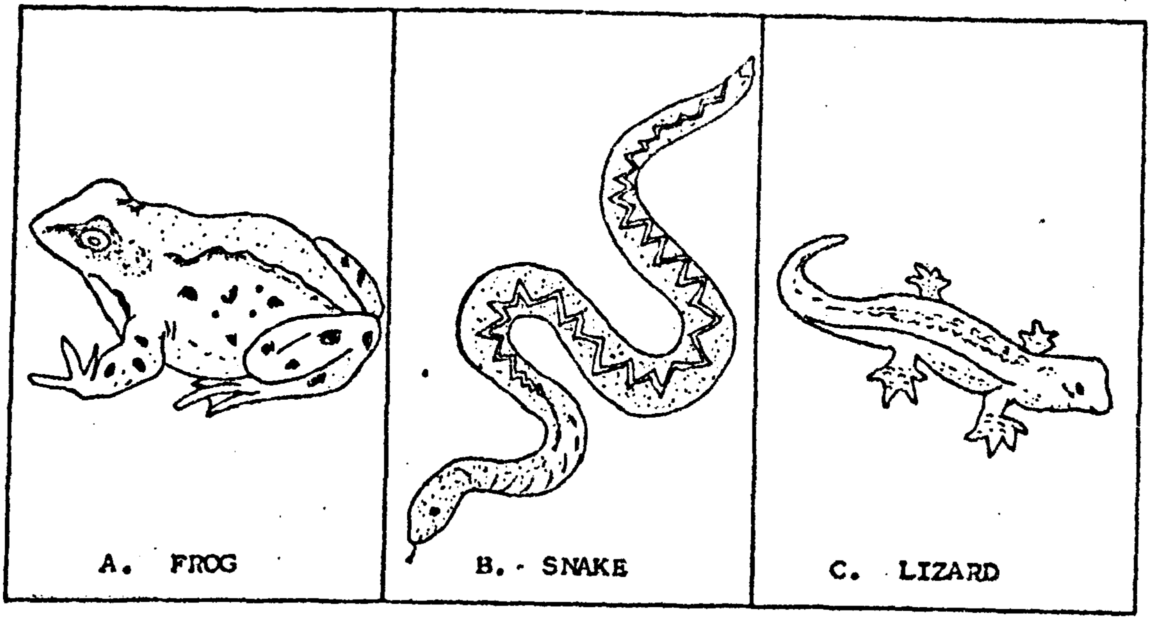


A. COMPASS B. MAGNET C. BINOCULARS

18. a) A and C are explorers' aids.

b) B is part of A.

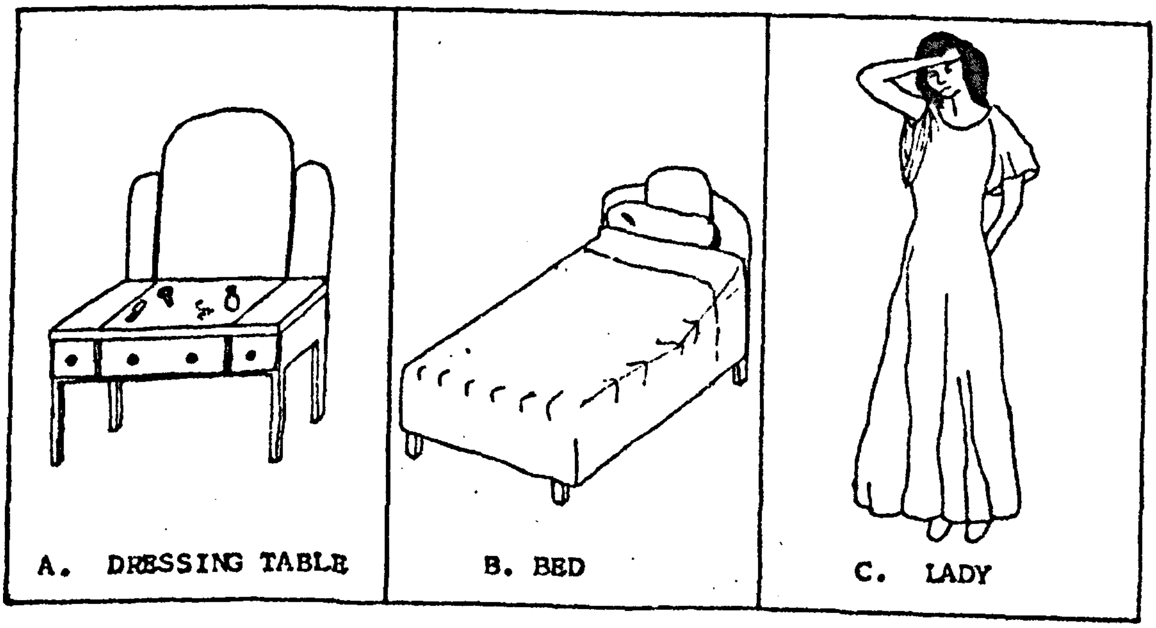
c) A and C have circular parts.



19. a) B and C are reptiles.

    b) A and C have four legs.

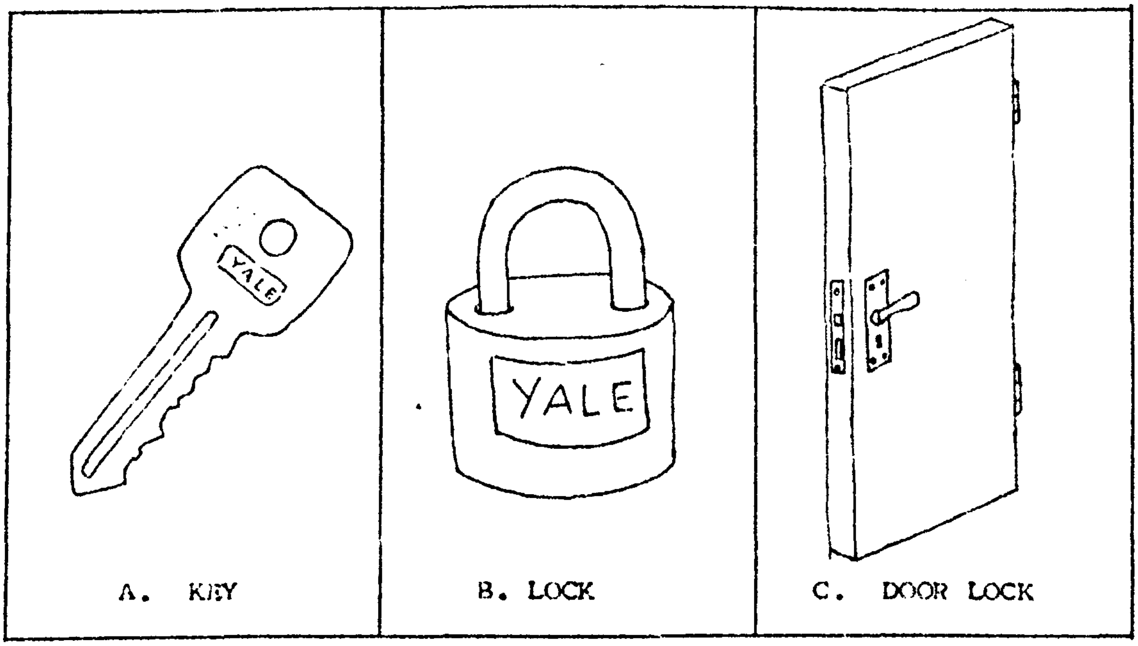
    c) B can feed on A.



20. a) A and B, both have four legs.

    b) C can sleep on B.

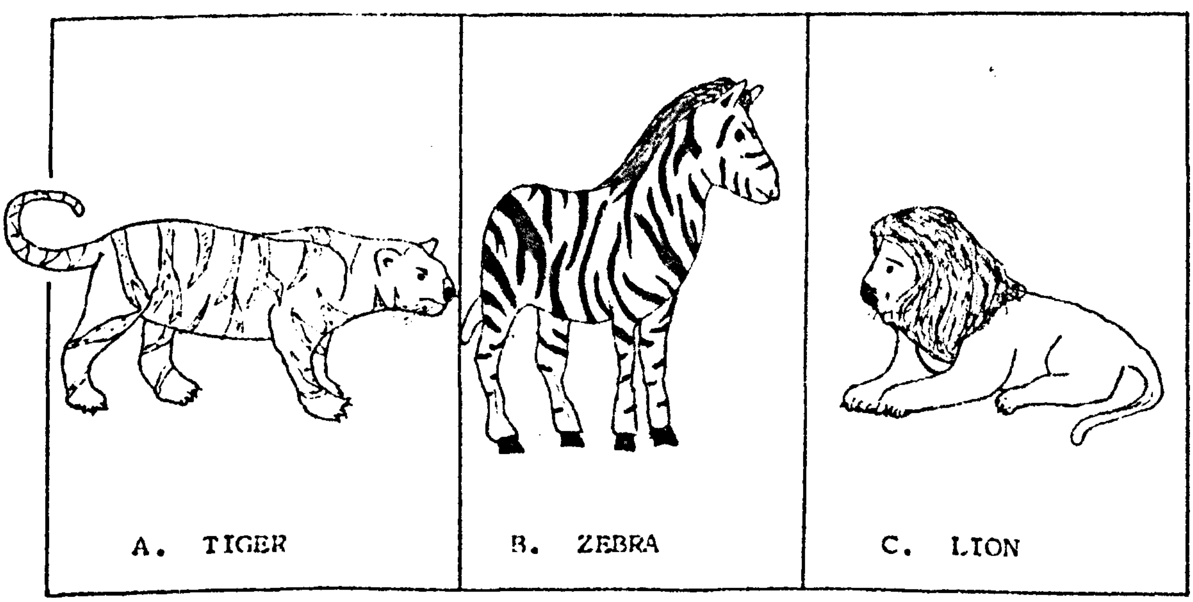
    c) A and B are bedroom furniture.



21. a) B and C are locking systems.

b) A can unlock B.

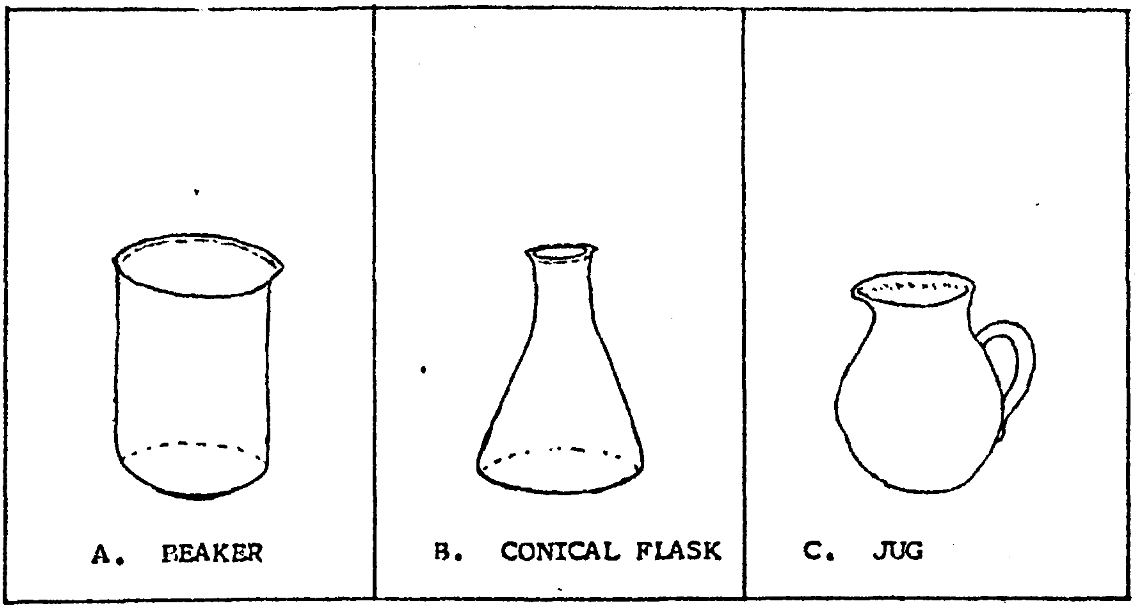
c) A and B, both have the word 'YALE' on them.



22. a) A and B, both have stripes on them.

b) C can attack B.

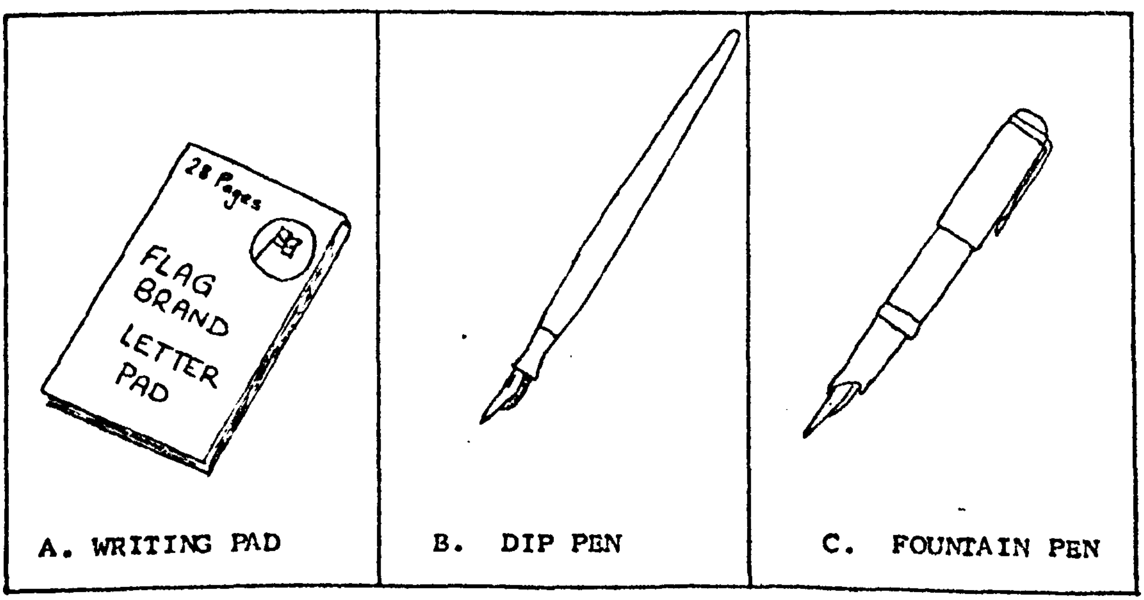
c) A and C are flesh-eating animals.



23. a) A and B are common laboratory glassware.

b) A and C, both have spout.

c) A can be used to pour liquid into B.



24. a) B and C, both have pointed tips.

b) C can be used to write on A.

c) B and C are writing devices.

NAME ______________________ FORM ______________

SCHOOL ______________________ SEX ______________

AGE ______ Years ______ Months DATE ______________

CONCEPTUAL PREFERENCE INVENTORY

ANSWER SHEET

ENTER THE LETTERS a, b or c IN THE APPROPRIATE COLUMN TO INDICATE YOUR MOST PREFERRED AND YOUR LEAST PREFERRED STATEMENT FOR EACH OF THE ITEMS.

ITEM	STATEMENT	
	MOST PREFERRED	LEAST PREFERRED
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
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18		
19		
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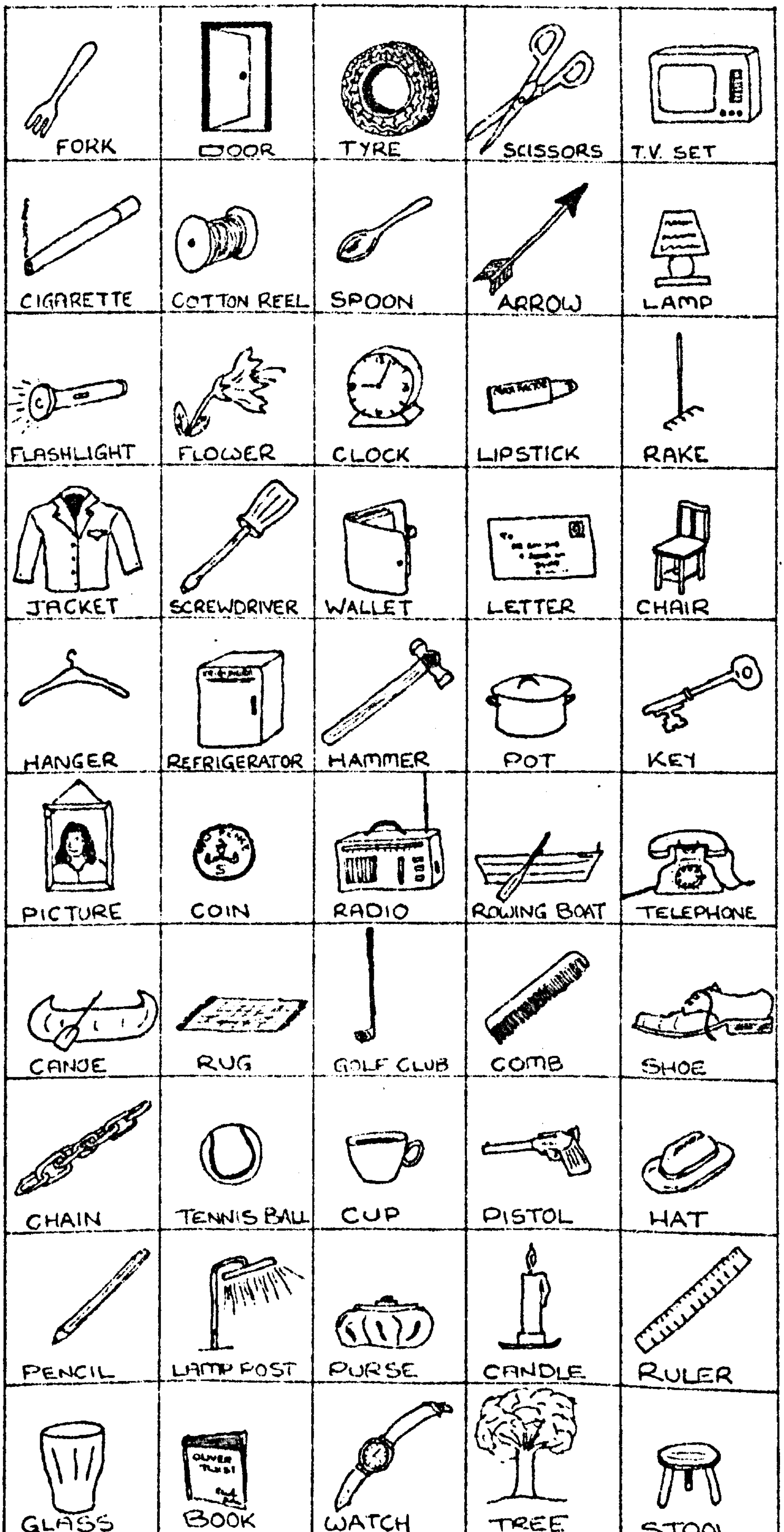
22		
23		
24		

APPENDIX A.4

OBJECT SORTING TEST

OBJECT SORTING TASK.



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Department of Education

OBJECT SORTING TASK.

NAME ______________________ FORM __________

SCHOOL ______________________ SEX __________

AGE ______ Years ______ Months DATE __________

You are provided with a sheet illustrating fifty different objects. Examine them carefully. Collect all the objects that seem to belong together in some way into groups. Also give your reason for grouping the objects together. The groups may be large or small and you may suggest as many groups as you like as long as the objects in each group belong together for a certain reason. Each object can be used only once. To help you to do this cross out the pictures as you use them to form groups. If there are any objects that really do not seem to fit into any of your groups you may leave them.

RECORD YOUR GROUPS AND YOUR REASONS IN THE TABLE PROVIDED.

DRAW A LINE ACROSS THE TABLE AFTER EACH GROUP THAT YOU MAKE.

Group number	Objects that go together	Reason

Group number	Objects that go together	Reason

APPENDIX A.5

(i) USES OF OBJECTS TEST

(ii) FLEXIBILITY MEASURE SCORING SCHEME

UNIVERSITY OF KEELE

Department of Education

USE OF OBJECTS TASK

NAME ______________________ FORM ____________

SCHOOL ______________________ SEX ____________

AGE ________ Years ______ Months. DATE ____________

In this task you are given a list of different objects and you are asked to state as many different uses as you can think of for each of the objects.

List the different uses in a column and number them carefully. If the space provided is not enough, use the back of the page.

I. State all the different ways you could use a NEWSPAPER.

____

____

____

____

____

____

____

II. State all the different ways you could use a BRICK.

____

____

____

____

____

____

____

III. State all the different ways you could use a PAPER CLIP.

IV. State all the different ways you could use a TIN CAN.

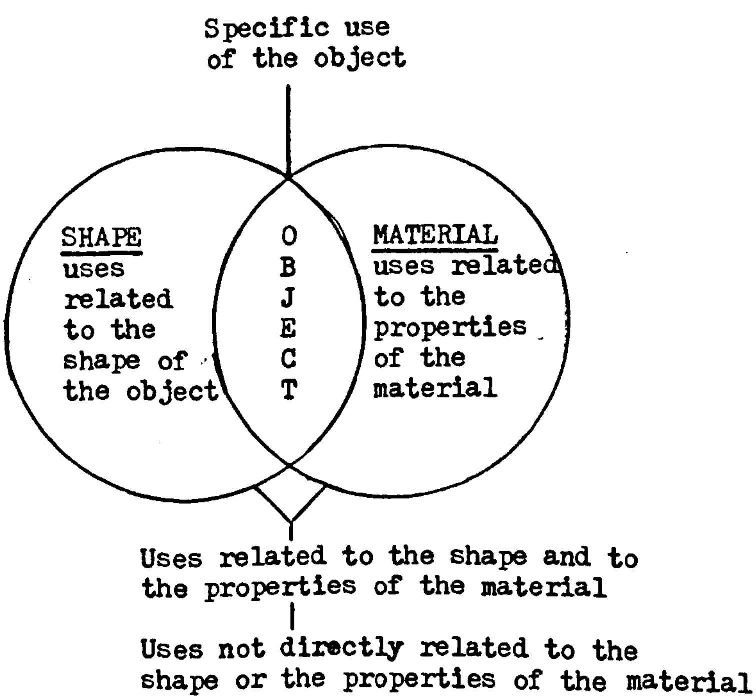
V. State all the different ways you could use a CORK.

VI. State all the different ways you could use a BLANKET.

Flexibility Measure Scoring Scheme

The responses given by the subjects in the Uses of Objects Test vary in quantity and quality. The fluency measure represents the total number of uses generated irrespective of the quality of the responses. The purpose of the flexibility measure was to distinguish between the quantity and quality of the responses i.e., the total number of uses and the different classes of uses generated. To arrive at this flexibility measure a person's responses had to be classified into different classes of uses.

In general the uses of objects may be classified into two main groups; uses relating to the specific function of the item, e.g. paper-clip - to clip pieces of paper together, and other uses that come about due to the special shape and/or to the properties of the material of which the item is made, e.g. newspaper - to soak up water. Also, it was found necessary to have a third broad category for uses not directly related to the shape or to the properties of the material, e.g. cork - collector's item. This broad scheme is summarised in the Figure below.



Categories of Uses

Based on the above scheme between ten to twelve classes of uses were recognised for each of the objects. They are listed below. The subject's responses were allocated to the different classes of uses to obtain his flexibility score (total number of different classes of uses generated for the six objects).

NEWSPAPER

A. Specific use of the item

1. for getting or giving information

B. General uses related to the shape and/or to the properties of the material

2. to paint/write on
3. spread over things to protect them
4. soak up/wipe liquids
5. fold and/or cut to make toys etc.
6. roll to form rod (to use as weapon)
7. crumple and stuff into things to keep shape
8. as wrapper to protect things
9. for burning to produce light and heat
10. for retaining heat
11. pulping for craft or recycling

C. Uses not directly related to the shape or to the properties of the material.

12. e.g. to give away for charity

BRICK

A. Specific use of the item

1. as construction material for building houses, walls etc.

B. General uses related to the shape and/or to the properties of the material.

2. as weight to hold things down
3. as weapon to smash, to kill etc.
4. for retaining heat
5. for making musical notes by striking
6. reshape to art form
7. for sharpening knives
8. to support things up
9. as wedge to prevent sliding

C. Uses not directly related to the shape or to the properties of the material.

10. e.g. as land markers

PAPER CLIP

A. Specific use of the item

1. to clip pieces of paper together

B. General uses related to the shape and/or to the properties of the material.

2. reshape to form other items, e.g. fishing hook
3. conduct electricity
4. to dig/pick with the sharp end
5. as stabilisers (small weights)
6. melt and recycle to make other things
7. magnetise it and use in games and experiments
8. link to form chain, craft work etc.
9. use as hook for hanging things up

C. Uses not directly related to the shape or to the properties of the material.

10. e.g. as book marker

TIN CAN

A. Specific use of the item

1. for storage and preservation of food, fruits etc.

B. General uses related to the shape and/or to the properties of the material.

2. cut and reshape to make other things
3. sharp edge for cutting and scratching
4. make noise by striking
5. shining surface for reflecting light
6. melt and recycle
7. container for odds and ends
8. good conductor - as cooking utensil
9. for playing games
10. as floats

C. Uses not directly related to the shape or to the properties of the material.

11. e.g. decorate it

CORK

A. Specific use of the item

1. as stopper

B. General uses related to the shape and/or to the properties of the material.

2. cut into shapes for craft work
3. cut and reshape to make other things, e.g. table mat
4. for sticking things on
5. as insulator
6. burn for heat, soot
7. for making toys
8. as floats
9. for use in games, e.g. as bullet in pop-gun

C. Uses not directly related to the shape or to the properties of the material.

10. e.g. collector's item

BLANKET

A. Specific use of the item

1. cover oneself with to keep warm

B. General uses related to the shape and/or to the properties of the material.

2. cut and make other articles of clothings
3. to clean and mop up liquids
4. burn for heat, smoke signal etc.
5. knot to form ladder
6. to cover up things for protection
7. as ground sheet
8. as wall decor
9. to protect against strong light and wind (shelter)
10. to put out fire
11. as sail, flag etc.

C. Uses not directly related to the shape or to the properties of the material.

12. e.g. give as present.

APPENDIX A.6

MATCHING FAMILIAR FIGURES TEST
(SAMPLE ITEMS)

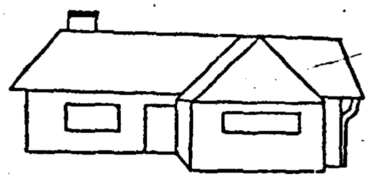
DIRECTIONS FOR MFF20

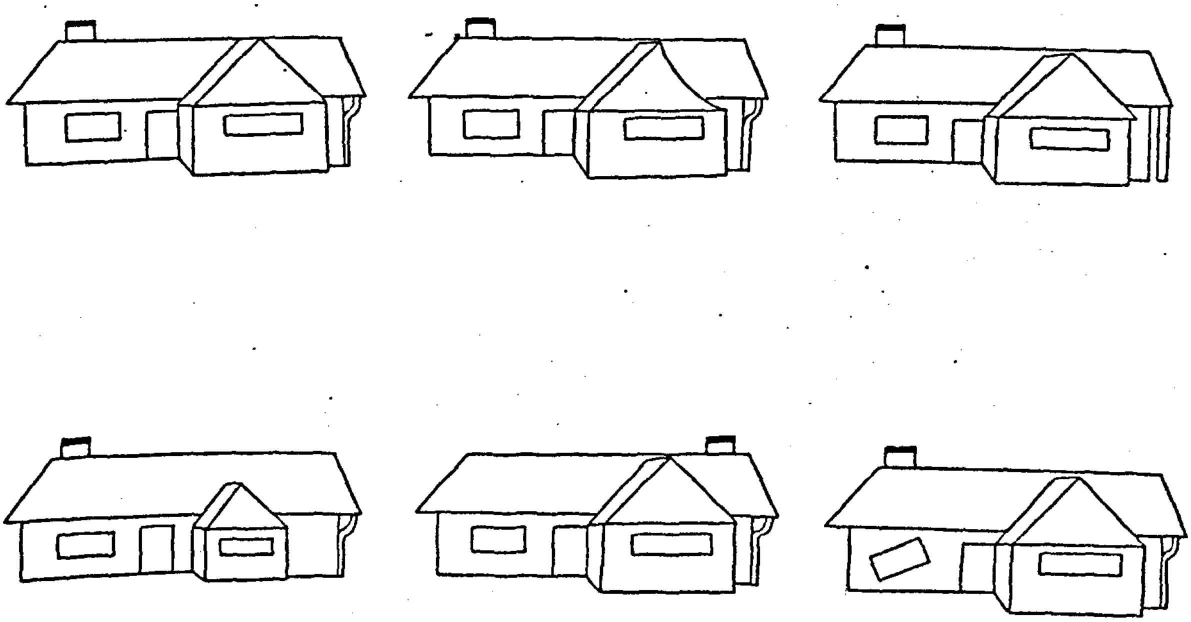
"I am going to show you a picture of something you know and then some pictures that look like it. You will have to point to the picture on this bottom page (point) that is just like the one on this top page (point). Let's do some for practice." E shows practice items and helps the child to find the correct answer. "Now we are going to do some that are a little bit harder. You will see a picture on top and six pictures on the bottom. Find the one that is just like the one on top and point to it."

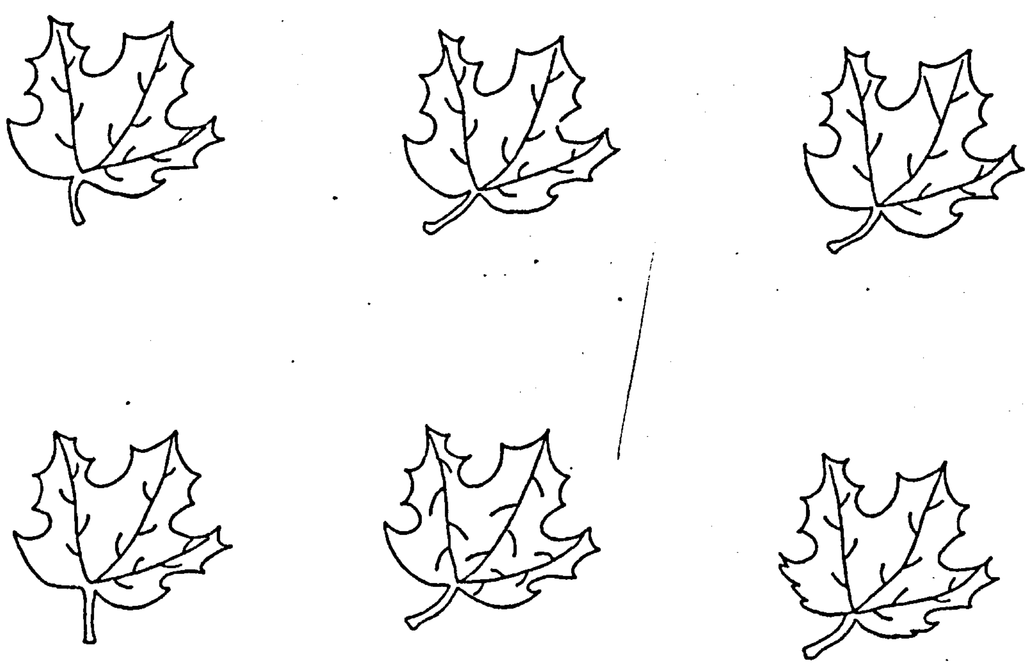
E will record latency to first response to the half-second, total number of errors for each item and the order in which the errors are made. If S is correct, E will praise. If wrong, E will say, "No, that is not the right one. Find the one that is just like this one (point)." Continue to code responses (not times) until child makes a maximum of six errors or gets the item correct. If incorrect, E will show the right answer.

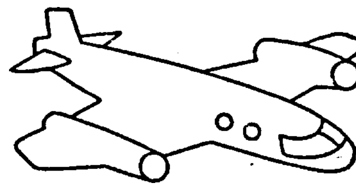
It is necessary to have a stand to place the test booklet on so that both the stimulus and the alternatives are clearly visible to the S at the same time. The two pages should be practically at right angles to one another.

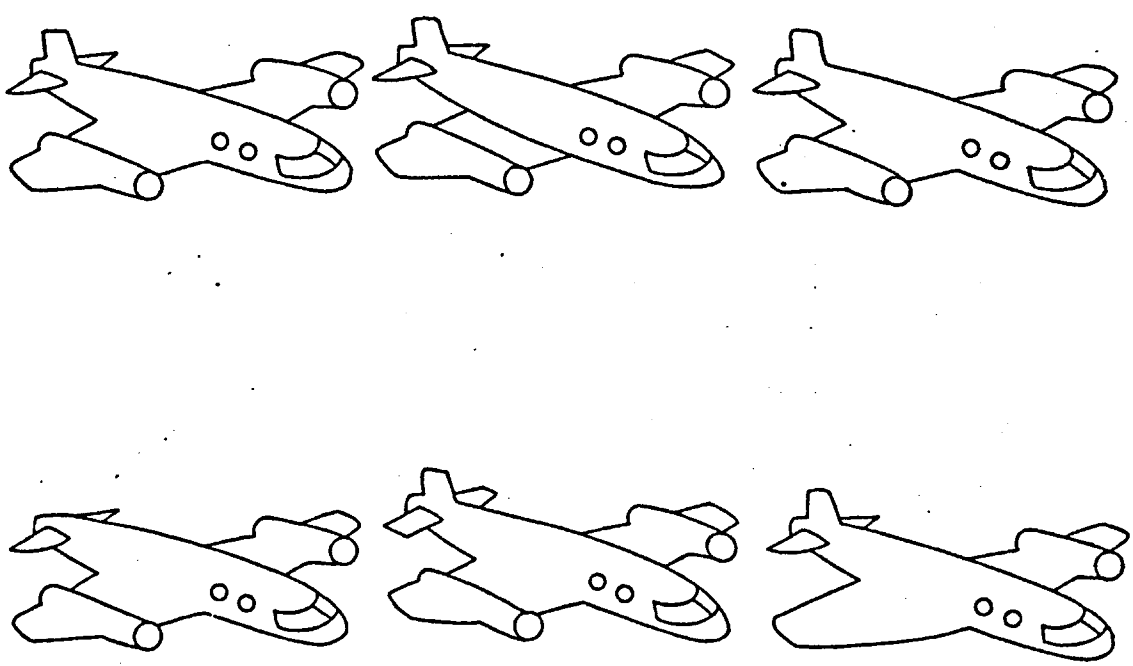
Note: It is desirable to enclose each page in clear plastic in order to keep the pages clean.

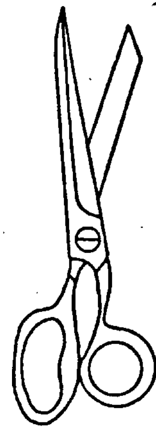


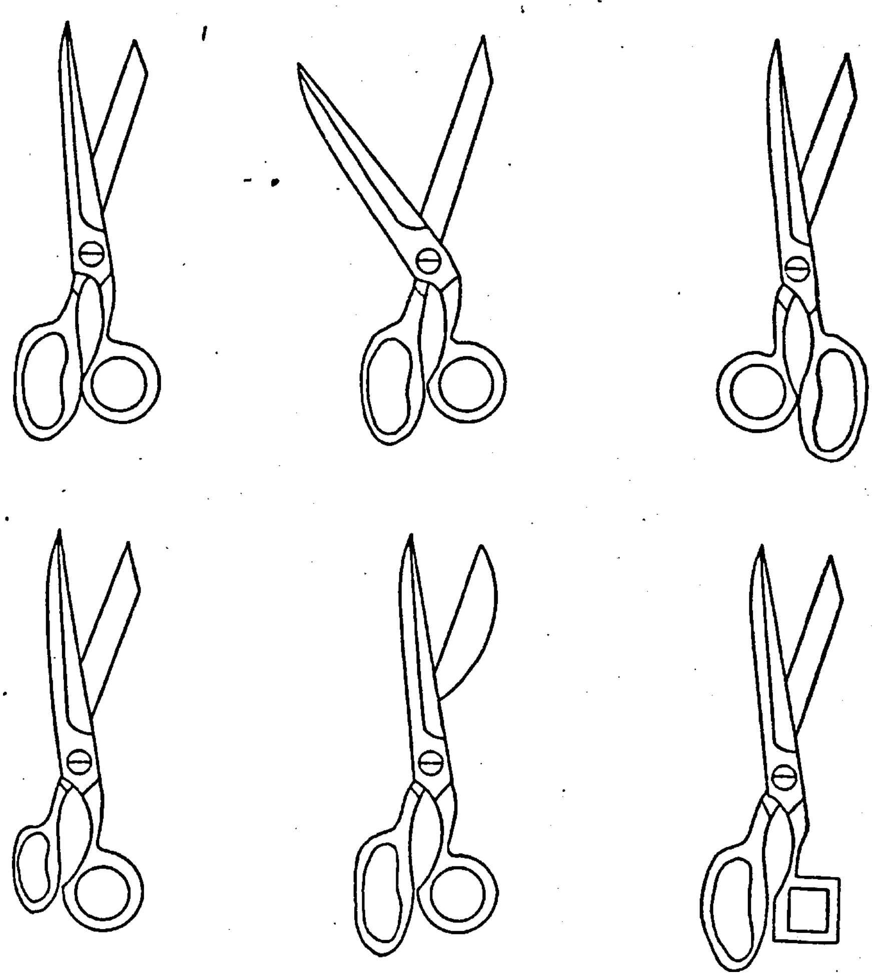


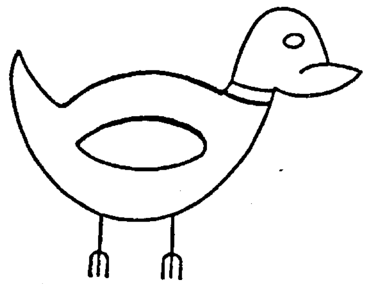


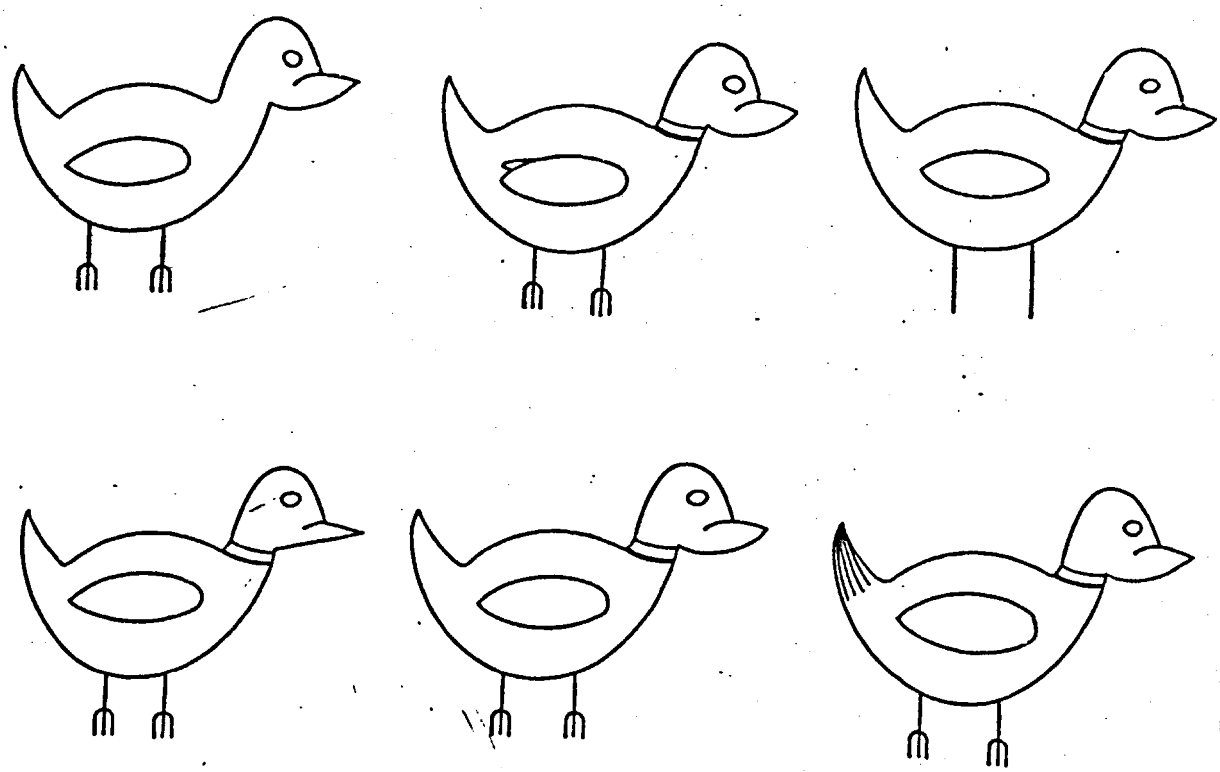












APPENDIX A.7

PREFERENCE FOR DIFFERENT

TYPES OF LEARNING

INVENTORY

UNIVERSITY OF KEELE

Department of Education

PREFERENCE FOR DIFFERENT TYPES OF LEARNING

NAME ______________________ FORM ________

SCHOOL ______________________ DATE ________

Previously you learned a number of rules for decoding scrambled words or coded words, or for completing letter and number series, or for finding the sum of odd number and constant difference series. The learning programme for learning these rules were written in two different forms:

TYPE 1 In this you were given examples which you had to study carefully and derive your own rules to solve the given problems.

TYPE 2 In this you were given the rules together with examples and you were asked to solve problems using the given rules.

Now we would like to find out your preference for the two types of learning to which you were exposed.

Listed below are a number of pairs of contrasting words which might be used to describe LEARNING. To indicate your preference or feeling about a particular type of learning situation circle one of the numbers along each scale. The numbers between the words allow you to say how much the learning situation was like either of the words. The closer your choice is to one end of the scale the stronger you feel that that end of the scale best describes the learning situation.

Example:

Suppose a learning situation had to be judged as to whether it was easy or difficult.

A student who found the situation very difficult, would circle a number close to the end of the scale marked DIFFICULT, eg.

	EASY	1	2	3	4	5	6	(7)	DIFFICULT
or	EASY	1	2	3	4	5	(6)	7	DIFFICULT

A student who found the situation slightly, but not very easy might have responded in this form,

EASY	1	2	(3)	4	5	6	7	DIFFICULT

A student who is uncertain about the answer, would have circled the mid-point of the scale which is number 4.

EASY	1	2	3	(4)	5	6	7	DIFFICULT

Remember the following points before you begin this exercise.

1) Consider the words at both ends of the scale before making your decision.
2) Circle ONE number only on a given scale.
3) DO NOT OMIT ITEMS; BE SURE TO CIRCLE A NUMBER FOR EACH SCALE.

turn over

LEARNING TYPE 1

I found learning by **deriving the rule on my own** from given examples and applying them to solve further problems to be

easy	1	2	3	4	5	6	7	difficult
simple	1	2	3	4	5	6	7	complicated
fast	1	2	3	4	5	6	7	slow
exciting	1	2	3	4	5	6	7	dull
clear	1	2	3	4	5	6	7	vague
interesting	1	2	3	4	5	6	7	boring
enjoyable	1	2	3	4	5	6	7	tiresome
challenging	1	2	3	4	5	6	7	unchallenging
useful	1	2	3	4	5	6	7	useless
demanding	1	2	3	4	5	6	7	undemanding
efficient	1	2	3	4	5	6	7	inefficient
straightforward	1	2	3	4	5	6	7	confusing

turn over

LEARNING TYPE 2

I found learning given rules with examples and applying them to solve further problems to be

easy	1	2	3	4	5	6	7	difficult
simple	1	2	3	4	5	6	7	complicated
fast	1	2	3	4	5	6	7	slow
exciting	1	2	3	4	5	6	7	dull
clear	1	2	3	4	5	6	7	vague
interesting	1	2	3	4	5	6	7	boring
enjoyable	1	2	3	4	5	6	7	tiresome
challenging	1	2	3	4	5	6	7	unchallenging
useful	1	2	3	4	5	6	7	useless
demanding	1	2	3	4	5	6	7	undemanding
efficient	1	2	3	4	5	6	7	inefficient
straightforward	1	2	3	4	5	6	7	confusing

APPENDIX B.1

SCRAMBLED WORDS TASK

i) Discovery version

ii) Expository version

iii) Post-test

NAME ______________________ FORM __________

SCHOOL ____________________ SEX __________

AGE ________ Years ______ Months DATE __________

A LEARNING PROGRAMME FOR DECODING SCRAMBLED WORDS

(DISCOVERY VERSION)

PROGRAMME COPY NUMBER __________

A. LOURDUSAMY

1979/80

UNIVERSITY OF KEELE,

DEPARTMENT OF EDUCATION.

INTRODUCTION

In this programme you will learn some rules for decoding scrambled words. First you will be given a group of scrambled words. Examine these words carefully, looking for a pattern or a rule to decode them and obtain the original word. Each rule which you are asked to find is based on a certain pattern of scrambling words. Once you have found the pattern, you are provided with further tasks to test whether your rule is correct.

The whole programme is divided into three sections A, B and C. Each section consists of four parts. If you are unable to work out the pattern or the rule for decoding the words in the first two parts of any one section, proceed to the next section. Return to the first section later, if you have the time.

As the result of this programme, you should be able to

1. state the three rules for decoding scrambled words;
2. decode scrambled words using the rules;
3. scramble words so that they can be decoded using the rules;
4. identify scrambled words that can be decoded using the rules.

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE PROGRAMME.

DECODING SCRAMBLED WORDS

SECTION A.

PART 1.

Given below are five words the letters of which have been scrambled in a particular way. Examine them carefully and look for a pattern to decode them to get the original words. Write the correct words in the spaces provided.

i) TOAC = ____________

ii) NOMEW = ____________

iii) RLOWEF = ____________

iv) MTREAS = ____________

v) RLAVOUF = ____________

PART 2.

Did you notice a pattern in decoding the above words? The pattern which you have found should be able to help you to decode scrambled words with any number of letters. Test whether the pattern which you have found is correct or not, by decoding the following four words.

i) RHAIC = ____________

ii) ERIDGB = ____________

iii) TORGEF = ____________

iv) HTRENGTS = ____________

PART 3.

If the pattern which you have found, has helped you to decode the words in PART 2, state it in the form of a rule.

RULE The original word can be obtained from the scrambled word by ____________________________

____

____

PART 4.

Using the rule which you have stated above, decode the following three sentences.

i) NOHJ TEFL EHT MOOR EATL.

____

ii) EHS DMITATEI EHT SCTIONA.

____

iii) YANM SRTISTA EID YREMATURELP.

____

SECTION B.

PART 1.

Here is a group of words which have been scrambled in a different way. Carefully examine them and identify a pattern for decoding them. Write the correct words in the spaces provided.

i) MPJU = ______________

ii) ADRO = ______________

iii) KEYMON = ______________

iv) PLEPEO = ______________

v) SUREPRES = ______________

PART 2.

The pattern which you have found should be concerned with decoding scrambled words with even number of letters only. Check to see whether the pattern which you have found is correct or not, by decoding the following words.

i) VECA = ______________

ii) TALMEN = ______________

iii) HINESUNS = ______________

iv) OSALPROP = ______________

PART 3.

If the pattern which you have recognised has helped you to decode the words in PART 2, state it in the form of a rule.

RULE . The original word can be obtained from the scrambled word by

___

___

___

PART 4.

Using the rule that you have stated above, decode the following three sentences.

i) EYTH EDNE REMO SHCA.

___

ii) KETA URFO INGSREAD.

___

iii) VEGI EMTH VENELE TOESPOTA CHEA.

___

SECTION C.

PART 1.

Here is another group of words the letters of which have been scrambled in a different way. Examine them carefully and identify a pattern for decoding the words.

i) RGAUE = ___

ii) ROBWN = ___

iii) SHTARAY = ___

iv) TUDSENT = ___

v) URNIFTURE = ___

PART 2.

The pattern which you have found should be concerned with decoding scrambled words with an odd number of letters only. Check to see whether the pattern which you have recognised works for decoding the following words.

i) ORPCH = ______________

ii) ROGUP = ______________

iii) TRASNGE = ______________

iv) ISEDASE = ______________

PART 3.

If you were able to decode the words in PART 2, using the pattern which you have recognised, state it in the form of a rule.

RULE ____

____

____

____

PART 4.

Using the rule that your have stated above, decode the following three sentences.

i) IEFLD RITFS RAE NJOYEABLE.

____

ii) HTE UNFNY OBY IKLES OINSE.

____

iii) RIDNK EMLON UIJCE AIDLY.

____

NAME ______________________ FORM __________

SCHOOL ______________________ SEX __________

AGE ________ Years ______ Months DATE __________

A LEARNING PROGRAMME FOR DECODING
SCRAMBLED WORDS

(EXPOSITORY VERSION)

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
DEPARTMENT OF EDUCATION.

INTRODUCTION.

In this programme you will be taught some rules for decoding scrambled words. First you will be given a group of words the letters of which have been scrambled. Then you will be shown how to decode the scrambled words. A general rule will be stated by which the scrambled words may be decoded. You are then provided with further exercises to practise the use of the rule.

The whole programme is divided into three sections A, B, and C. Each section consists of four parts. If you are unable to work out any of the tasks, proceed to the next one. Return to the unsolved tasks later if you have the time.

As the result of this programme, you should be able to

1. state the three rules for decoding scrambled words;
2. decode scrambled words using the rules;
3. scramble words so that they can be decoded using the rules;
4. identify scrambled words that can be decoded using the rules.

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE PROGRAMME.

DECODING SCRAMBLED WORDS

SECTION A.

PART 1.

Given below are five words the letters of which have been scrambled in a particular way.

i) TOAC ii) NOMEW iii) RLOWEF iv) MTREAS v) RLAVOUF

If you examine the scrambled words carefully you will notice that if you exchange the position of the first and the last letter in each word as shown below you can get the original words.

i) TOAC = COAT

ii) NOMEW = WOMEN

iii) RLOWEF = FLOWER

iv) MTREAS = STREAM

v) RLAVOUF = FLAVOUR

PART 2.

A general rule may be stated by which this type of scrambled words can be decoded. The rule can be used to decode scrambled words with any number of letters.

RULE The original word can be obtained from the scrambled word by exchanging the positions of the first and the last letter in the scrambled word.

PART 3.

Given below are four scrambled words. Try to decode them using the general rule stated in PART 2. Write the correct words in the spaces provided.

i) RHAIC = ____________

ii) ERIDGB = ____________

iii) TORGEF = ____________

iv) HTRENGTS = ____________

PART 4.

Given below are three sentences consisting of scrambled words. Decode the sentences using the rule you have learned.

i) NOHJ TEFL EHT MOOR EATL.

____

ii) EHS DMITATEI EHT SCTIONA.

____

iii) YANM SRTISTA EID YREMATURELP.

____

SECTION B.

PART 1.

Now we go to a second group of scrambled words the letters of which have been scrambled in a different way.

i) MPJU ii) ADRO iii) KEYMON iv) PLEPEO v) SUREPRES

If you examine the above words carefully you will notice that you can get the original word by reversing the position of the first half of the scrambled word with the second half as shown below.

i) MPJU	=	JUMP
ii) ADRO	=	ROAD
iii) KEYMON	=	MONKEY
iv) PLEPEO	=	PEOPLE
v) SUREPRES	=	PRESSURE

PART 2.

A general rule may be stated by which this type of scrambled words can be decoded. The rule can be used to decode scrambled words with an even number of letters only.

RULE To get the original word reverse the position of the first half of the scrambled word with the second half.

PART 3.

Given below are four scrambled words. Try to decode them using the general rule stated in PART 2. Write the correct words in the spaces provided.

i) VECA = ______

ii) TALMEN = ______

iii) HINESUNS = ______

iv) OSALPROP = ______

PART 4.

Given below are three sentences consisting of scrambled words. Decode the sentences using the rule you have learned.

i) EYTH EDNE REMO SHCA.

______

ii) KETA URFO INGSREAD.

______

iii) VEGI EMTH VENELE TOESPOTA CHEA.

______

SECTION C.

PART 1.

Here is another group of scrambled words the letters of which have been scrambled in a different way.

i) RGAUE ii) ROBWN iii) SHTARAY iv) TUDSENT v) URNIFTURE

If you examine the words carefully you will notice that if you move the middle letter of the scrambled words and place it at the front of the remaining letters you can get the original words.

i) RGAUE = ARGUE

ii) ROBWN = BROWN

iii) SHTARAY = ASHTRAY

iv) TUDSENT = STUDENT

v) URNIFTURE = FURNITURE

PART 2.

A general rule may be stated by which this type of scrambled words can be decoded. The rule can be used to decode scrambled words with an odd number of letters only.

RULE. To get the original word move the middle letter of the scrambled word to the front of the remaining letters.

PART 3.

Given below are four scrambled words. Try to decode them using the general rule stated in PART 2. Write the correct words in the spaces provided.

i) ORPCH = ______________

ii) ROGUP = ______________

iii) TRASNGE = ______________

iv) ISEDASE = ______________

PART 4.

Given below are three sentences consisting of scrambled words. Decode the sentences using the rule you have learned in this section.

i) IEFLD RITPS RAE NJOYEABLE.

____

ii) HTE UNFNY OBY IKLES OINSE.

____

iii) RIDNK EMLON UIJCE AIDLY.

____

NAME ______________________ SCHOOL ______________________

UNIVERSITY OF KEELE

Department of Education

SCRAMBLED WORDS TEST A

ANSWER ALL ITEMS ON THE TEST PAPER. GIVE YOUR ANSWERS IN THE SPACE PROVIDED.

Item 1.

In the programme for decoding scrambled words you learned THREE rules by which scrambled words may be decoded. These rules were concerned with changing the position of certain letters in the scrambled words to obtain the original word. State the three rules and number them 1, 2 and 3, respectively.

Rule number ______ ____

____

____

____

Rule number ______ ____

____

____

____

Rule number ______ ____

____

____

____

turn over

Item 2

Decode the following scrambled words and indicate the rule used by putting the rule number in the appropriate column.

Scrambled word	Original word	Rule used
i) POUS		
ii) ANCOE		
iii) ELETBRAC		
iv) LORSAI		
v) AUGNHTY		
vi) SURIOUF		

Item 3

Scramble the following words so that they can be décoded using the three rules. Use each rule twice for scrambling the words. Indicate the rule by which the scrambled word that you have formed may be decoded.

Original word	Scrambled word	Rule number
i) LADY		
ii) DRINK		
iii) CLOCK		
iv) LETTER		
v) PALACE		
vi) HONESTY		

APPENDIX B.2

CODED WORDS TASK

i) Discovery version

ii) Expository version

iii) Post-test

NAME ______________________________ FORM ____________

SCHOOL ____________________________ SEX ____________

AGE ________ Years ______ Months. DATE ____________

A LEARNING PROGRAMME FOR DECODING CODED WORDS

(DISCOVERY VERSION)

PROGRAMME COPY NUMBER ______

A. LOURDUSAMY

1979/80

UNIVERSITY OF KEELE,

DEPARTMENT OF EDUCATION.

INTRODUCTION.

In a previous unit, you learned three rules for decoding scrambled words. In this unit you will learn some rules for decoding coded words.

First you will be given a group of coded words. Examine them carefully and look for a pattern to decode them to get the original words. Each pattern or rule which you are asked to find is based on a certain basic way of changing a letter or letters in the word. Once you have identified the pattern, you are provided with further tasks to test whether your rule is correct.

The whole unit is divided into four sections A, B, C and D. Each section consists of three parts. If you are unable to identify the pattern or the rule for decoding the words in any one section, proceed to the next section. Return to the section later, if you have the time.

As the result of this unit, you should be able to

i) state the four rules for decoding coded words;

ii) decode coded words using the rules;

iii) code words so that they can be decoded using the rules.

You may find it helpful to refer to the alphabet while working through this unit:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE PROGRAMME.

DECODING CODED WORDS

SECTION A.

PART 1.

Given below are five words which have been changed in a particular way. Examine them carefully and look for a pattern to decode them to get the original word. Write down the correct word in space provided.

i) LADZ = ______________

ii) DRINL = ______________

iii) WATES = ______________

iv) STREAN = ______________

v) REFUSAM = ______________

PART 2.

Did you notice a specific pattern of change in the above words? The pattern which you have identified should be concerned with changing a particular letter in the word. Test whether the pattern which you have identified is correct or not by decoding the following five words.

i) JUMQ = ______________

ii) CHAIS = ______________

iii) CANOF = ______________

iv) STORN = ______________

v) LAUGI = ______________

PART 3.

If the pattern which you have identified, has helped you to decode the words in PART 2, state it in the form of a rule.

RULE The original word can be obtained from the coded word by ________

____

____

SECTION B.

PART 1.

Here is a second group of coded words which have been formed in a different way. Examine them carefully and identify a pattern for decoding them to obtain the original words. Write the correct words in the spaces provided.

i) KEARN = ____________

ii) RWEET = ____________

iii) VOMAN = ____________

iv) GAPPY = ____________

v) FENTLE = ____________

PART 2.

Test whether the pattern which you have recognised in decoding the words in PART 1, is correct or not by decoding the following five words.

i) TPSET = ____________

ii) AREAD = ____________

iii) QULER = ____________

iv) SHEATRE = ____________

v) LOTHER = ____________

PART 3.

If the pattern which you have identified, has helped you to decode the words in PART 2, state it in form of a rule.

RULE . The original word can be obtained from the coded word by ________

____

____

____

SECTION C.

PART 1.

Here is a third group of coded words which have been formed in a different way. Examine them carefully and identify a pattern for decoding them. Write the correct words in the spaces provided.

i) CIFFERENU = ____________

ii) RTRANGF = ____________

iii) BARRZ = ____________

iv) ROUQ = ____________

v) JNOX = ____________

PART 2.

The pattern which you have recognised should be concerned with changing certain letters in the word. Test whether the pattern which you have identified is correct or not by decoding the following words.

i) SABLF = ____________

ii) RAILOS = ____________

iii) VHEAU = ____________

iv) BHURCHET = ____________

v) CBSL = ____________

PART 3.

If the pattern which you have identified, has helped you to decode the words in PART 2, state it in the form of a rule.

RULE ____

____

____

SECTION D.

PART 1.

Here is another group of coded words formed in a different way. Examine them carefully and identify a pattern for decoding them. Write the correct words in the spaces provided.

i) GJTI = ____________

ii) XBML = ____________

iii) TBNF = ____________

iv) CSFBE = ____________

v) HSPVQ = ____________

PART 2.

Test whether the pattern which you have recognised in decoding the words in PART 1, is correct or not by decoding the following words.

i) XSJUF = ____________

ii) DBUDI = ____________

iii) GJFME = ____________

iv) HFOUMF = ____________

v) QBUUFSO = ____________

PART 3.

If the pattern which you have identified, has helped you to decode the words in PART 2, state it in the form of a rule.

RULE ____

____

____

NAME ______________________ FORM __________

SCHOOL ______________________ SEX __________

AGE ________ Years ______ Months. DATE __________

A LEARNING PROGRAMME FOR DECODING

CODED WORDS

(EXPOSITORY VERSION)

PROGRAMME COPY NUMBER ______

A. LOURDUSAMY

1979/80

UNIVERSITY OF KEELE,

DEPARTMENT OF EDUCATION.

DECODING CODED WORDS.

SECTION A.

PART 1.

Given below are five coded words which have been formed in a particular way.

i) LADZ ii) DRINL iii) WATES iv) STREAN v) REFUSAM

Our task is to examine the words and find a pattern for decoding them. If you examine the coded words carefully you will notice that if we changed the last letter of the word with the letter coming before it in the alphabet as shown below we can get the original word.

i) LADZ	=	LADY
ii) DRINL	=	DRINK
iii) WATES	=	WATER
iv) STREAN	=	STREAM
v) REFUSAM	=	REFUSAL

PART 2.

From the examples we have studied in PART 1, we can state a rule to decode such coded words as follows:

RULE Replace the last letter in the coded word with the letter coming before it in the alphabet to obtain the original word.

PART 3.

Given below are five more coded words. Using the rule stated in PART 2, decode them. Write the correct words in the spaces provided.

i) JUMQ	=	____________
ii) CHAIS	=	____________
iii) CANOF	=	____________
iv) STORN	=	____________
v) LAUGI	=	____________

SECTION F.

PART 1.

Here is a second group of coded words which have been formed in a different way.

i) KEARN ii) RWEET iii) VOMAN iv) GAPPY v) FENTLE

Our task is to examine the words and find a pattern for decoding them. If you examine the coded words carefully you will notice that if we change the first letter of the word with the letter following it in the alphabet as shown below we can get the original word.

i) KEARN = LEARN

ii) RWEET = SWEET

iii) VOMAN = WOMAN

iv) GAPPY = HAPPY

v) FENTLE = GENTLE

PART 2.

From the examples we have studied in PART 1, we can state a rule to decode such coded words as follows:

RULE 2. Replace the first letter in the coded word with the letter following it in the alphabet to obtain the original word.

PART 3.

Given below are five more coded words. Using the rule stated in PART 2, decode them. Write the correct words in the spaces provided.

i) TPSET = ____________

ii) AREAD = ____________

iii) QULER = ____________

iv) SHEATRE = ____________

v) LOTHER = ____________

SECTION C

PART 1.

Here is a third group of coded words which have been formed in a different way.

i) CIFFERENU ii) RTRANGF iii) BARRZ iv) ROUQ v) JNOX

Our task is to examine the words and find a pattern for decoding them. If you examine the coded words carefully you will notice that if we change the first letter of the word with the letter following it and the last letter in the word with the letter before it in the alphabet, we can get the original word.

i) CIFFERENU = DIFFERENT

ii) RTRANGF = STRANGE

iii) BARRZ = CARRY

iv) ROUQ = SOUP

v) JNOX = KNOW

PART 2.

From the examples we have studied in PART 1, we can state a rule for decoding such coded words as follows:

RULE To obtain the original word from the coded word, replace the first letter in the coded word with the letter following it in the alphabet and the last letter with the letter coming before it in the alphabet.

PART 3.

Given below are five more coded words. Using the rule stated in PART 2, decode them.

i) SABLF = ____________

ii) RAILOS = ____________

iii) VHEAU = ____________

iv) BHURCHET = ____________

v) CESL = ____________

SECTION D

PART 1.

Here is another group of coded words formed in a different way.

i) GJTI ii) XBML iii) TBNF iv) CSFBE v) HSPVQ

Our task is to examine the words and find a pattern for decoding them. If you examine the coded words carefully you will notice that if we change each letter in the coded word with the letter coming before it in the alphabet, we can get the original word.

i) GJTI = FISH

ii) XBML = WALK

iii) TBNF = SAME

iv) CSFBE = BREAD

v) HSPVQ = GROUP

PART 2.

From the examples we have studied in PART 1, we can state a rule for decoding such coded words as follows:

RULE To obtain the original word from the coded word replace each of the letters in the coded word with the letter coming before it in the alphabet

---

PART 3.

Given below are five more coded words. Using the rule stated in PART 2, decode them. Write the correct words in the spaces provided.

i) XSJUF = ____________

ii) DBUDI = ____________

iii) GJFME = ____________

iv) HFOUMF = ____________

v) QBUUFSO = ____________

NAME ______________________ SCHOOL ______________________

UNIVERSITY OF KEELE

Department of Education

CODED WORDS TEST

ANSWER ALL ITEMS ON THE TEST PAPER. GIVE YOUR ANSWERS IN THE SPACE PROVIDED.

Item 1 In the unit on decoding coded words you learned FOUR rules by which coded words may be decoded. These rules were concerned with changing one or more letters in the word. State the FOUR rules and number them 1, 2, 3 and 4, respectively.

Rule Number ____ ______________________________

____

____

Rule Number ____ ______________________________

____

____

Rule Number ____ ______________________________

____

____

Rule Number ____ ______________________________

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turn over

Item 2 Decode the following coded words and indicate the rule used by putting the rule number in the column provided.

Coded word	Original word	Rule used
i) LOAG		
ii) EBODF		
iii) RTRAX		
iv) IUDGE		
v) BHAIS		
vi) BOOL		
vii) BLEAN		
viii) GSPOU		

Item 3 Code the following words so that they can be decoded using the rules which you have learned. Use each rule twice to code the words. Indicate the rule by which the coded word that you have formed may be decoded by putting the rule number in the column provided.

Original word	Coded word	Rule number
i) CHAIN		
ii) SCREAM		
iii) CHURCH		
iv) JEWEL		
v) INSECT		
vi) ROCK		
vii) LOGIC		
viii) SUSPECT		

APPENDIX B.3

LETTER SERIES AND NUMBER SERIES TASKS

i) Discovery version

ii) Expository version

INTRODUCTION

In this programme you will learn some rules for completing letter series and number series.

You will be given series of letters and numbers. Your job is to examine them carefully, identify a pattern in them and use it to complete the series. To be successful in this task first you will have to divide the letters or the numbers into sets and then look for a pattern in the sets.

After you are successful in a task you will be required to state a rule by which you can help a friend to complete the task.

The whole programme consists of eight tasks and eight exercises. If you are unable to do a particular task go to the next. Return to the unsolved task if you have the time.

You may find it helpful to refer to the alphabet while working through th letter series:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE PROGRAMME.

COMPLETING LETTER SERIES

TASK 1

Examine the letter series below carefully and fill in the next letter in the series.

i) atbataatbat____

ii) mnamnbmnamn____.

State a rule by which you can guide a friend to complete such a series.

____

____

____

____

____

EXERCISE 1

Use the rule that you have stated to complete the series given below.

i) xyaxybxyaxy___

ii) stbstastbst___

iii) klbklaklbkl___

____

TASK 2

Examine the letter series below carefully and fill in the next three letters in the series.

i) krtkstktt_____

ii) gipgjpgkp_____

State a rule by which you can guide a friend to complete such a series.

____

____

____

____

____

EXERCISE 2

Using the rule that you have statec complete the letter series below by filling in the next three letters in each case.

i) dpxdqxdrx__________

ii) ratrbtrct__________

iii) fumfvmfwm__________

COMPLETING LETTER SERIES

TASK 1

Examine the letter series below carefully and fill in the next letter in the series.

i) atbataatbat____

ii) mnamnbmnamn____.

State a rule by which you can guide a friend to complete such a series.

____

____

____

____

____

EXERCISE 1

Use the rule that you have stated to complete the series given below.

i) xyaxybxyaxy___

ii) stbstastbst___

iii) klbklaklbkl___

____

TASK 2

Examine the letter series below carefully and fill in the next three letters in the series.

i) krtkstktt_____

ii) gipgjpgkp_____

State a rule by which you can guide a friend to complete such a series.

____

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EXERCISE 2

Using the rule that you have statec complete the letter series below by filling in the next three letters in each case.

i) dpxdqxdrx_________

ii) ratrbtrct_________

iii) fumfvmfwm_________

COMPLETING LETTER SERIES

TASK 1

Examine the letter series below carefully and fill in the next letter in the series.

i) atbataatbat____

ii) mnamnbmnamn____.

State a rule by which you can guide a friend to complete such a series.

____

____

____

____

____

EXERCISE 1

Use the rule that you have stated to complete the series given below.

i) xyaxybxyaxy__

ii) stbstastbst__

iii) klbklaklbkl__

____

TASK 2

Examine the letter series below carefully and fill in the next three letters in the series.

i) krtkstktt_____

ii) gipgjpgkp_____

State a rule by which you can guide a friend to complete such a series.

____

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EXERCISE 2

Using the rule that you have statec complete the letter series below by filling in the next three letters in each case.

i) dpxdqxdrx_________

ii) ratrbtrct_________

iii) fumfvmfwm_________

COMPLETING LETTER SERIES

TASK 1

Examine the letter series below carefully and fill in the next letter in the series.

i) atbataatbat____

ii) mnamnbmnamn____.

State a rule by which you can guide a friend to complete such a series.

____

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EXERCISE 1

Use the rule that you have stated to complete the series given below.

i) xyaxybxyaxy___

ii) stbstastbst___

iii) klbklaklbkl___

____

TASK 2

Examine the letter series below carefully and fill in the next three letters in the series.

i) krtkstktt_____

ii) gipgjpgkp_____

State a rule by which you can guide a friend to complete such a series.

____

____

____

____

____

EXERCISE 2

Using the rule that you have statec complete the letter series below by filling in the next three letters in each case.

i) dpxdqxdrx__________

ii) ratrbtrct__________

iii) fumfvmfwm__________

TASK 3

Examine the letter series below carefully and fill in the next two letters in the series.

i) sttuuv______

ii) mbncod______

State a rule by which you can guide a friend to complete such a series.

EXERCISE 3

Using the rule that you have stated, complete the letter series given below by filling in the next two letters in each case.

i) cddeef______

ii) kllmmn______

iii) wpxqyr______

TASK 4

Examine the letter series given below carefully and fill in the next three letters in the series.

i) tmesldrkc______

ii) xhdwgcvfb______

State a rule by which you can guide a friend to complete such a series.

EXERCISE 4

Using the rule that you have stated, complete the letter series given below by filling the next three letters.

i) fnremqdlp______

ii) leukdtjcs______

iii) qyhpxgowf______

TASK 5

Examine the number series given below carefully and fill in the next three numbers in the series.

i) 041042043________

ii) 524525526________

State a rule by which you can guide a friend to complete such a series.

____

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____

EXERCISE 5

Using the rule you have stated, fill the next three figures in each of the series given below.

i) 453454455________

ii) 382383384________

iii) 875876877________

TASK 6

Examine the number series given below carefully and fill in the next two numbers in the series.

i) 786756________

ii) 324354________

State a rule by which you can guide a friend to complete such a series.

____

____

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EXERCISE 6

Using the rule which you have stated, complete the series given below by filling in the next two figures.

i) 213243________

ii) 344556________

iii) 796857________

TASK 7

Examine the number series given below carefully and fill in the next three numbers in the series.

i) 421533645________

ii) 533645757________

State a rule by which you can guide a friend to complete such a series.

____

____

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____

EXERCISE 7

Using the rule that you have stated, fill the next three figures in each of the series given below.

i) 342454566________

ii) 123235347________

iii) 650762874________

TASK 8

Examine the number series given below carefully and fill in the next four figures.

i) 123443211234________

ii) 756336577563________

State a rule by which you can guide a friend to complete such a series.

____

____

____

____

____

EXERCISE 8

Using the rule that you have stated, complete the series given below by filling in the next four figures.

i) 193883911938________

ii) 257667522576________

iii) 513773155137________

NAME ______________________ FORM __________

SCHOOL ______________________ SEX __________

AGE _______ Years _________ Months DATE __________

A LEARNING PROGRAMME FOR COMPLETING

LETTER SERIES AND NUMBER SERIES

(EXPOSITORY VERSION)

PROGRAMME COPY NUMBER LN 170

A. LOURDUSAMY

1979/80

UNIVERSITY OF KEELE,

DEPARTMENT OF EDUCATION.

INTRODUCTION.

In this programme you will be taught some rules for completing letter series and number series.

First you will be given a series of letters or a series of numbers and shown the pattern that is present in them. A general rule will be stated by which the series can be completed. You will then be given further exercises to practise the use of the rule.

The whole programme consists of eight tasks and eight exercises. If you are unable to do a particular exercise go to the next one. Return to it later if you have the time.

You may find it helpful to refer to the alphabet while working through the letter series:

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE PROGRAMME.

TASK 3

In this task we will have to fill in the next two letters in the series.

i) st/tu/uv/________

ii) mb/nc/od/________

If you examine the above letter series you will notice that they consist of two-letter sets with the two letters in each set changing to the next letter in the alphabet. Therefore the answer to task 3(i) is vw and to task 3 (ii) is pe. Fill in the answers.

EXERCISE 3

Using the above guide fill in the next two letters in each of the series given below.

i) cddeef________

ii) kllmmn________

iii) wpxqyr________

TASK 4

In this task we will have to fill in the next three letters in the series.

i) tme/sld/rkc/__________

ii) xhd/wgc/vfb/__________

If you examine the above letter series you will notice that they consist of three-letter sets with all the letters in each set changing to the letter coming before it in the alphabet. Therefore the answer to task 4(i) is qjb and to task 4 (ii) is uea. Fill in the answers.

EXERCISE 4

Using the above guide fill in the next three letters in each of the series given below.

i) fnremqdlp__________

ii) leukdtjcs__________

iii) qyhpxgowf__________

TASK 5

In this task we will have to fill in the next three figures in the series.

i) 041/042/043/______

ii) 524/525/526/______

If you examine the above number series you will notice that they consist of three-figure sets with the first two figures remaining unchanged and the third figure increasing in value by one. Therefore the answer to task 5(i) is 044 and to task 5(ii) is 527. Fill in the answers.

EXERCISE 5

Using the above guide fill in the next three figures in each of the series given below.

i) 643454455________

ii) 382383384________

iii) 875876877________

TASK 6

In this task we will have to fill in the next two numbers in the series.

i) 78/67/56/_______

ii) 32/43/54/_______

If you examine the above number series you will notice that they consist of two-figure sets with the successive sets differing by ± 11 units. Therefore the answer to task 6(i) is 34 and to task 6(ii) is 76. Fill in the answers.

EXERCISE 6

Using the above guide fill in the next two figures in each of the series given below.

i) 213243_________

ii) 344556_________

iii) 796857_________

TASK 7

In this task we will have to fill in the next three figures in the series.

i) 421/533/645/________

ii) 533/645/757/________

If you examine the above number series you will notice that they consist of three-figure sets with the first and the second figure increasing by one unit and the third figure increasing by two units in the successive sets of figures. Therefore the answer to task 7(i) is 757 and to task 7(ii) is 869. Fill in the answers.

EXERCISE 7

Using the guide fill in the next three figures in each of the series given below.

i) 342454566________

ii) 123235347________

iii) 650762874________

TASK 8

In this task we will have to fill in the next four figures in the series.

i) 1234/4321/1234/______________

ii) 7563/3657/7563/______________

If you examine the number series you will notice that they consist of four-figure sets with the successive sets having the figures reversed. Therefore the answer to task 8(i) is 4321 and to task 8(ii) is 3657. Fill in the answers.

EXERCISE 8

Using the above guide fill in the next four figures in each of the series given below.

i) 193883911938__________

ii) 257667522576__________

iii) 513773155137__________

APPENDIX B.4

SUM OF ODD-NUMBERS SERIES TASK

i) Discovery version

ii) Expository version

NAME ______________________ FORM ____________

SCHOOL ____________________ SEX ____________

AGE ________ Years ______ Months DATE ____________

A LEARNING PROGRAMME FOR FINDING THE SUM OF ODD NUMBER SERIES

(DISCOVERY VERSION)

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INTRODUCTION

In this learning unit you are given a series of addition problems called the " Sum of Odd-numbers Problem ". Each problem consists of a series of odd numbers always beginning with one (eg. 1, 3, 5, 7, 9, 11) but can be of any length. Your task is to try to discover how to find the sum of these series of numbers without adding them in the usual way. Some hints are provided to help you think along a right path.

After you have found a rule and tested it with a number of problems, you will be asked to express the rule in the form of a general statement by which you can help your friends solve such problems.

The unit is divided into different parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

If you are unable to derive a general rule in Part 1, proceed to Part 2.

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE UNIT.

SUM OF ODD-NUMBERS SERIES

PART 1 Given below are three series of odd numbers, all beginning with one. Your task is to discover a way of finding the sum of this type of series without adding the numbers in the usual way. Below each series you are given the number of figures (N) in the series. For example in Series A there are four figures, i.e. 1, 3, 5 and 7.

Series A	Series B	Series C
1	1	1
3	3	3
5	5	5
7	7	7
____	9	9
____	____	11
	____	____
		____
N = 4	N = 5	N = 6

Now add each series in the usual way and write the answer in the space provided . See whether you can recognise any relationship between the number of figures in the series and the sum of the series.

If you recognise a relationship,state in the space provided below.

____

____

If you are unable to recognise a relationship, proceed to Part 2.

PART 2 Look at the figures given below. They represent the problems in Part 1 in a different way. In the figures, each X represents one unit, and the dotted lines form a square. The length of the side of the square represents the number of figures in the series. For example, in Figure 1 the length of the side of the square is 4 units since there are four figures in the series.

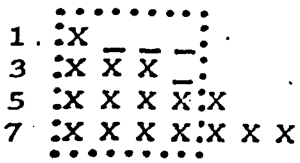

Figure 1

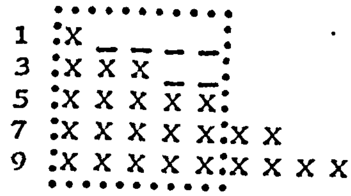

Figure 2

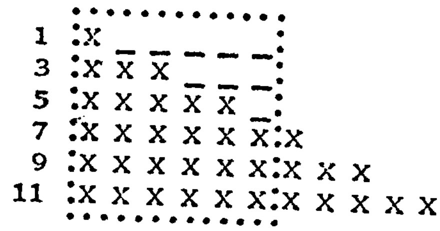

Figure 3

Do you notice any relationship between the number of Xs left outside the square and the empty places inside the square? If so, state it.

____

____

Can the Xs left outside the square be fitted exactly into the empty places inside the square? YES / NO (delete as appropriate)

If your answer is NO, check again.

If your answer is YES, put the Xs in the empty places and delete the Xs outside the square.

Can you think of a way of getting the sum of the Xs in the square now without counting them? If so, state it.

____

____

PART 3 Test whether the general method that you have recognised in Part 1 and/or in Part 2 for getting the sum of odd-numbers series beginning with one is correct or not by applying it to the problems given below.

Find the sum of the odd-number series using the general method and without adding in the usual way. Show all your workings. Then check your answer by adding the numbers. DO NOT ERASE OR DELETE THE ANSWER IF IT IS WRONG.

a) 1, 3, 5, 7, 9, 11, 13, 15 = ______________________

b) 1X, 3X, 5X, 7X, 9X, 11X, 13X = ______________________

c) 1n, 3n, 5n, 7n, 9n, 11n, 13n, 15n, 17n = ______________________

Does your general method work for these series also? YES / NO (delete as appropriate)

If you answer is NO, proceed to Section B on page 5.

If your answer is YES, state your general method in form of a rule.

Sum of Odd-Numbers Rule ______________________

____

____

PART 4 Given below are four more problems for you to solve using the rule which you have stated in Part 3. Show all your workings.

a) Find the sum of the first TEN odd numbers. Write the numbers down first and then calculate the sum of the series.

b) Find the sum of the first TWELVE odd numbers in a y-series. Complete the series and calculate the sum of the series.

1y, 3y, 5y,

c) Find the sum of the first FIFTEEN odd numbers in a p-series. First write down the series and then calculate the sum of the series.

d) A man is paid one pound for his first hour of work and he is paid two pounds more for every successive hour of work. He works for EIGHT hours.

How much would he earn for i) his last hour of work,

ii) his total work?

NAME ____________________ FORM ____________

SCHOOL ____________________ SEX ____________

AGE ________ Years ________ Months DATE ____________

A LEARNING PROGRAMME FOR FINDING
THE SUM OF ODD NUMBER
SERIES

(EXPOSITORY VERSION)

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INRODUCTION

In this unit you will be taught how to find the sum of a series of odd numbers which always begins with one (eg. 1, 3, 5, 7, 9, 11) but is of any length.

The rule which you will learn in this unit will show you how to find the sum of such series of numbers without adding the numbers in the usual way.

After you have learned the rule for finding the sum of odd-numbers series, you will be given a number of problems to try.

The unit is divided into different parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

If you are unable to solve a given problem, proceed to the next one. Return to the unsolved problem, if you have the time.

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE UNIT.

SUM OF ODD-NUMBERS SERIES

PART 1 Given below are three series of odd numbers, all beginning with one. Below each series you are given the number of figures (N) in the series. In Series A, there are four figures, i.e. 1, 3, 5, 7; in Series B, there are five figures, i.e. 1, 3, 5, 7, 9; and in Series C, there are six figures, i.e. 1, 3, 5, 7, 9, 11.

Series A	Series B	Series C
1	1	1
3	3	3
5	5	5
7	7	7
	9	9
		11
S = 16	S = 25	S = 36
N = 4	N = 5	N = 6

You are now going to learn a rule which will help you to find the sum of such odd numbers series without having to add the numbers in the usual way. Look carefully at the sum of the series (S) and the number of figures (N) in each of the series. You will notice that they are related. The sum of the series is always equal to the square of the number of figures in the series; i.e. $S = N^2$

A general rule may be stated as follows:

Sum of Odd-numbers Rule The sum of a series of odd numbers beginning with one is equal to the square of the number of figures in the series.

PART 2 We can look at this problem in a different way. Study the figures given below. In the figures, each X represents one unit and the dotted line forms a square enclosing most of the Xs. The length of the side of the square represents the number of figures (N) in the series. For example in figure 1, the length of the side of the square is equal to 4 units since there are four figures in the first series.

```
   .........
1  :X _ _ _:
3  :X X X _:
5  :X X X X:X
7  :X X X X:X X X
   .........
```

Figure 1

```
   ...........
1  :X _ _ _ _:
3  :X X X _ _:
5  :X X X X X:
7  :X X X X X:X X
9  :X X X X X:X X X X
   ...........
```

Figure 2

```
    .............
1   :X _ _ _ _ _:
3   :X X X _ _ _:
5   :X X X X X _:
7   :X X X X X X:X
9   :X X X X X X:X X X
11  :X X X X X X:X X X X X
    .............
```

Figure 3

If you look at the figures carefully you will notice that the number of Xs left outside the square is equal to the number of empty places inside the square. Hence all the units in an odd-numbers series beginning with one can be fitted in a square, the side of which is equal to the number of figures in the series.

Enter the Xs inside the square and delete the Xs outside the square.

How can we now get the sum of Xs inside the square without counting them? We can get the sum of the Xs inside the square by just squring the length of the side of the square. For example, for the first series it is equal to (4 x 4) X = 16X.

Hence the sum of a series of odd numbers beginning with one is equal to the square of the number of figures in the series.

PART 3 Apply the general rule which you have learned in Part 1 and Part 2 to the problems given below.

Find the sum of each of the series given below. Show all your workings. Then check your answers by adding the numbers in the series. DO NOT ERASE OR DELETE THE ANSWER IF IT IS WRONG.

a) 1, 3, 5, 7, 9, 11, 13, 15 = ______________________

b) 1X, 3X, 5X, 7X, 9X, 11X, 13X = ______________________

c) 1n, 3n, 5n, 7n, 9n, 11n, 13n, 15n, 17n = ______________________

Does the general rule work for these series also? YES / NO (delete as appropriate)

If your answer is NO, proceed to section B on page 4.

If your answer is YES, proceed to Part 4 below

PART 4 Given below are four more problems. Solve them using the rule which you have learned. Show all your workings.

a) Find the sum of the first TEN odd numbers. Write down the numbers and then calculate the sum of the series.

____

____

b) Find the sum of the first TWELVE odd numbers in a y-series. Complete the series and calculate the sum of the series.

1y, 3y, 5y, ______________________________

____

c) Find the sum of the first FIFTEEN odd numbers in a p-series. Write down the series and calculate the sum of the series.

____

____

d) A man is paid one pound for his first hour of work and is paid two pounds more for every successive hour of work. He works for EIGHT hours.

How much would he earn for i) his last hour of work,

ii) his total work?

____

____

____

TASK 7

In this task we will have to fill in the next three figures in the series.

i) 421/533/645/_______

ii) 533/645/757/_______

If you examine the above number series you will notice that they consist of three-figure sets with the first and the second figure increasing by one unit and the third figure increasing by two units in the successive sets of figures. Therefore the answer to task 7(i) is 757 and to task 7(ii) is 869. Fill in the answers.

EXERCISE 7

Using the guide fill in the next three figures in each of the series given below.

i) 342454566_______

ii) 123235347_______

iii) 650762874_______

TASK 8

In this task we will have to fill in the next four figures in the series.

i) 1234/4321/1234/_______

ii) 7563/3657/7563/_______

If you examine the number series you will notice that they consist of four-figure sets with the successive sets having the figures reversed. Therefore the answer to task 8(i) is 4321 and to task 8(ii) is 3657. Fill in the answers.

EXERCISE 8

Using the above guide fill in the next four figures in each of the series given below.

i) 193883911938_______

ii) 257667522576_______

iii) 513773155137_______

APPENDIX B.5

CHEMISTRY LEARNING TASKS

Unit 1.
- i) Discovery version
- ii) Expository version

Unit 2.
- i) Discovery version
- ii) Expository version

Unit 3.
- i) Discovery version
- ii) Expository version

Unit 4.
- i) Discovery version
- ii) Expository version

Data Sheets

- i) Periodic Table
- ii) Table of combining powers of elements and radicals

Summary Sheets

- i) Unit 1
- ii) Unit 2
- iii) Unit 3
- iv) Unit 4

NAME ____________________ FORM __________

SCHOOL ____________________ DATE __________

A LEARNING PROGRAMME ON COMBINING POWER AND CHEMICAL FORMULAE

(DISCOVERY VERSION)

UNIT 1

PROGRAMME COPY NUMBER ______

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INTRODUCTION

In this programme you will find the relationship between the combining power of an element and the position of the element in the Periodic Table and learn to work out chemical formulae. The combining power of an element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3 the elements X,Y and Z have combining powers of 1,2 and 3, respectively, since they combine with 1,2 and 3 units of chlorine.

The whole programme consists of FOUR learning units. You will do one unit per lesson over the next two weeks.

UNIT 1. The relationship between the combining power and the group number of an element.

UNIT 2. Chemical formulae of binary compounds.

UNIT 3. Combining powers of radicals and chemical formulae involving them.

UNIT 4. Combining powers of transition metals and chemical formulae involving them.

Each of the above units is divided into different parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

To help you work through these learning units, you are provided two Data Sheets. Data Sheet A is the PERIODIC TABLE of the elements and Data Sheet B gives the symbols and combining powers of some common elements and radicals.

How to work through each learning unit.

1. Place Data Sheet A and Data Sheet B where you can see them as you work through the unit.
2. Read the information given in each part of the unit carefully and consider what task you are required to complete.
3. For most parts of the unit you will have to examine the data sheets and enter the required information in the spaces provided.
4. Inspect the information you have as a whole and form a general idea or rule which can help you to do further exercises.
5. If you are unable to do a given task in the unit, proceed to the next.

You may find it helpful to know the Roman and Arabic numerials.

Roman numerials:	I	II	III	IV	V	VI	VII	VIII	IX	X
Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT I. The relationship between the combining power of an element and the group number of the element.

PART 1.

The Periodic Table is a classification of the elements based on one of their fundamental characteristics. Hence, the Periodic Table gives us useful information to help us study the characteristics of the elements in an orderly manner.

In the Periodic Table the elements are divided into Periods and Groups. The Periods are the horizontal rows of elements in the table. For example, Period 2 consists of the elements lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine and neon. The Periods are numbered in the table using the Arabic numerials, 1, 2, 3, etc.

The vertical columns of elements in the table form the Groups. For example, Group II consists of the elements beryllium, magnesium, calcium, strontium, barium and radium. The Groups are numbered in the table using the Roman numerials I, II, III, etc. The elements in a group show similarities in their properties.

In this unit you are going to find out the relationship between the combining power of an element and the group number of the element in the Periodic Table.

Given below is a list of names of elements found in the first four groups of the Periodic Table. Using Data Sheet A and Data Sheet B fill in the required information in the table below.

Element	Symbol	Combining power of the element.	Group number of the element.
sodium			
rubidium			
calcium			
barium			
aluminium			
carbon			

Do you notice any relationship between the combining power of an element and the group number of the element in the Periodic Table? If so, state it.

____

____

____

PART 2.

Given below is another list of names of elements found in the first four groups of the Periodic Table. Using the Data Sheet A and the relationship which you have noticed in Part 1, determine the combining power of the elements.

Element	Symbol	Group number of the element.	Combining power of the element.
silicon			
magnesium			
boron			
potassium			
strontium			
tin			

PART 3.

Now let us find out how the combining power of the elements in Group V, VI and VII of the Periodic Table are related to their group number. Using Data Sheet A and Data Sheet B, fill in the required information in the table below.

Element	Symbol	Combining power of the element.	Group number of the element
chlorine			
bromine			
oxygen			
sulphur			
nitrogen			

Examine Data Sheet A and find out how many groups of elements there are in the Periodic Table, including the inert gases, Group 0; but excluding the transition metal.

Total number of groups of elements in the Periodic Table = ______________

Do you notice any relationship between the total number of groups of elements in the Periodic Table , the group number of an element and the combining power of the element? If so, state it.

____

____

____

PART 4.

Given below is another list of names of elements found in Group V, VI and VII of the Periodic Table. Using Data Sheet A and the relationship which you have noticed in Part 3, determine the combining power of the elements.

Element	Symbol	Group number of the element	Combining power of the element
fluorine			
antimony			
phosphorus			
iodine			
selenium			

PART 5.

Complete the following statements.

(i) The combining power of an element present in Group I, II, III or IV of the Periodic Table is equal to ______________________________.

(ii) The combining power of an element present in Group V, VI or VII of the Periodic Table is equal to ______________________________
____.

NAME ____________________ FORM __________

SCHOOL ____________________ DATE __________

A LEARNING PROGRAMME ON COMBINING POWER AND CHEMICAL FORMULAE

(EXPOSITORY VERSION)

UNIT 1

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INTRODUCTION

In this programme you will learn about the relationship between the combining power of an element and the position of the element in the Periodic Table and learn to work out chemical formulae.

The combining power of the element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3, the elements X, Y, and Z have combining power of 1, 2 and 3, respectively, since they combine with 1, 2 and 3 units of chlorine.

The whole programme consists of FOUR learning units. You will do one unit per lesson over the next two weeks.

UNIT 1. The relationship between the combining power and the group number of an element.

UNIT 2. Chemical formulae of binary compounds.

UNIT 3. Combining power of radicals and chemical formulae involving them.

UNIT 4. Combining powers of transition metals and chemical formulae involving them.

Each of the above units is divided into parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

To help you to work through these learning units, you are provided with two Data Sheets. Data Sheet A is the PERIODIC TABLE of the elements, and Data Sheet B gives the symbols and combining powers of some common elements and radicals.

How to work through each learning unit.

1. Place Data Sheet A and Data Sheet B where you can see them as you work through the unit.
2. Read the information given in each part of the unit.
3. Study the general rule given and examine how it fits the information in the table provided.
4. Do the exercises, using the information in the Data Sheets provided and what you have learned in the unit.
5. If you are unable to do a particular exercise in the unit, proceed to the next exercise.

You may find it helpful to know the Roman and Arabic numerials.

Roman numerials:	I	II	III	IV	V	VI	VII	VIII	IX	X
Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT 1. The relationship between the combining power of an element and the group number of the element.

PART 1.

The Periodic Table is a classification of the elements based on one of their fundamental characteristics. Hence, the Periodic Table gives us useful information to help us study the characteristics of the elements in an orderly manner.

In the Periodic Table the elements are divided into Periods and Groups. The Periods are the horizontal rows of elements in the table. For example, Period 2 consists of the elements lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine and neon. The Periods are numbered in the table using the Arabic numerials 1, 2, 3, etc.

The vertical columns of elements in the table form the Groups. For example, Group II consists of the elements beryllium, magnesium, calcium, strontium, barium and radium. The Groups are numbered in the table using the Roman numerials I, II, III, etc. The elements in a group show similarities in their properties.

In this unit you are going to learn about the relationship between the combining power of an element and the group number of the element in the Periodic table.

Given below is a list of names of elements found in the first four groups of the Periodic Table together with their symbol, combining power and group number. Study them carefully.

Element	Symbol	Combining power of the element	Group number of the element
sodium	Na	1	I
rubidium	Ru	1	I
calcium	Ca	2	II
barium	Ba	2	II
aluminium	Al	3	III
carbon	C	4	IV

If you have examined the above table carefully, you will notice that the combining power of an element present in Group I, II, III or IV of the Periodic Table is equal to its group number. For example, sodium is in Group I and therefore its combining power is 1; barium is in Group II and therefore its combining power is 2.

PART 4.

Given below is another list of names of elements found in Group V, VI or VII of the Periodic Table. Using Data Sheet A and what you have learned in Part 3, determine the combining power of the elements.

Element	Symbol	Group number of the element	Combining Power of the element
fluorine			
antimony			
phosphorus			
iodine			
selenium			

PART 5.

Complete the following statements.

(i) The combining power of an element present in Group I, II, III or IV of the Periodic Table is equal to ______________________.

(ii) The combining power of an element present in Group V, VI or VII of the Periodic Table is equal to ______________________

____.

NAME ______________________ FORM __________

SCHOOL ______________________ DATE __________

A LEARNING PROGRAMME ON COMBINING POWER
AND CHEMICAL FORMULAE

(DISCOVERY VERSION)

UNIT 2

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INTRODUCTION

In this programme you will find the relationship between the combining power of an element and the position of the element in the Periodic Table and learn to work out chemical formulae. The combining power of an element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3 the elements X,Y and Z have combining powers of 1,2 and 3, respectively, since they combine with 1,2 and 3 units of chlorine.

The whole programme consists of FOUR learning units. You will do one unit per lesson over the next two weeks.

UNIT 1. The relationship between the combining power and the group number of an element.

UNIT 2. Chemical formulae of binary compounds.

UNIT 3. Combining powers of radicals and chemical formulae involving them.

UNIT 4. Combining powers of transition metals and chemical formulae involving them.

Each of the above units is divided into different parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

To help you work through these learning units, you are provided two Data Sheets. Data Sheet A is the PERIODIC TABLE of the elements and Data Sheet B gives the symbols and combining powers of some common elements and radicals.

How to work through each learning unit.

1. Place Data Sheet A and Data Sheet B where you can see them as you work through the unit.
2. Read the information given in each part of the unit carefully and consider what task you are required to complete.
3. For most parts of the unit you will have to examine the data sheets and enter the required information in the spaces provided.
4. Inspect the information you have as a whole and form a general idea or rule which can help you to do further exercises.
5. If you are unable to do a given task in the unit, proceed to the next.

You may find it helpful to know the Roman and Arabic numerials.

Roman numerials:	I	II	III	IV	V	VI	VII	VIII	IX	X
Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT 2. Formulae of binary compounds

PART 1.

The combining powers of elements are used to find chemical formulae. Elements react together to form chemical compounds. When only two elements react to form a compound, the compound formed is called a binary compound. Calcium reacts with chlorine to form calcium chloride. Calcium chloride is a binary compound since it contains only two elements, namely, calcium and chlorine.

The compound calcium chloride can be represented by the chemical formula, $CaCl_2$. The calcium chloride formula, $CaCl_2$ consists of 1 unit of calcium and 2 units of chlorine. Hence, a chemical formula is a shorthand way of representing the name of a chemical compound.

Writing a chemical formula involves the use of symbols and the combining powers of the elements. Also, the chemical formula has a metallic and a non-metallic component. The first named element in the compound is the metallic component and the second named element is the non-metallic component. For example, in calcium chloride, calcium is the metallic component and chloride (chlorine) is the non-metallic component. Note that the name of the non-metallic component of a binary compound always ends in -ide.

In this unit you will find out how to work out and write chemical formulae of binary compounds.

turn over

Given below is a list of names of some common binary compounds and their chemical formulae. With the help of Data Sheet B, analyse the chemical formulae and complete the table.

COMPOUND	FORMULA	Metallic component	Combining power of metallic component Cp	Number of units of metallic component n	Total combining power of metallic units n x Cp	Non-metallic component	Combining power of non-metallic component Cp'	Number of units of non-metallic component n'	Total combining power of non-metallic units n' x Cp'
calcium chloride	$CaCl_2$	Ca	2	1	1 x 2 = 2	Cl	1	2	2 x 1 = 2
potassium iodide	KI								
aluminium chloride	$AlCl_3$								
aluminium oxide	Al_2O_3								
aluminium nitride	AlN								
barium oxide	BaO								
germanium oxide	GeO_2								

i) What do you notice about the total combining power of the metallic and the non-metallic component of a chemical compound?

____

____

ii) How is the total combining power of the metallic and the non-metallic component of a compound made equal when the combining powers of the elements are not equal?

____

____

PART 2.

Given below is a list of names of binary compounds. Using the Data Sheet B and what you have found about the formula of binary compounds in Part 1, work out the chemical formulae of these compounds.

COMPOUND	Symbol of metallic element	Combining power of metallic element	Symbol of non-metallic element	Combining power of non-metallic element	Number of metallic element units required	Number of non-metallic element units required	FORMULA
magnesium nitride							
bismuth chloride							
strontium bromide							
antimony sulphide							
lithium oxide							
tin oxide							

PART 3.

A, B and C are three metallic elements having combining powers 1, 2 and 3, respectively.

X, Y and Z are three non-metallic elements having combining powers 1, 2 and 3, respectively.

Work out the formula of compounds formed between:

Components	Formula
A and Y	
C and X	
B and Z	
A and Z	
B and Y	
C and Y	

NAME ______________________ FORM __________

SCHOOL ______________________ DATE __________

A LEARNING PROGRAMME ON COMBINING POWER AND CHEMICAL FORMULAE

(EXPOSITORY VERSION)

UNIT 2

PROGRAMME COPY NUMBER _______

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education

INTRODUCTION

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The combining power of the element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3, the elements X, Y, and Z have combining power of 1, 2 and 3, respectively, since they combine with 1, 2 and 3 units of chlorine.

The whole programme consists of FOUR learning units. You will do one unit per lesson over the next two weeks.

UNIT 1. The relationship between the combining power and the group number of an element.

UNIT 2. Chemical formulae of binary compounds.

UNIT 3. Combining power of radicals and chemical formulae involving them.

UNIT 4. Combining powers of transition metals and chemical formulae involving them.

Each of the above units is divided into parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

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2. Read the information given in each part of the unit.
3. Study the general rule given and examine how it fits the information in the table provided.
4. Do the exercises, using the information in the Data Sheets provided and what you have learned in the unit.
5. If you are unable to do a particular exercise in the unit, proceed to the next exercise.

You may find it helpful to know the Roman and Arabic numerials.

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Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT 2. Formulae of binary compounds

PART 1.

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The compound calcium chloride can be represented by a chemical formula, $CaCl_2$. The calcium chloride formula, $CaCl_2$, consists of one unit of calcium and two units of chlorine. Hence, a chemical formula is a shorthand way of representing the name of a chemical compound.

Writing a chemical formula involves the use of symbols and the combining powers of the elements. Also, the chemical formula has a metallic component and a *non-metallic component*. The first named element in the compound is the metallic component and the second named element is the *non-metallic* component. For example, in calcium chloride, calcium is the metallic component and chloride (chlorine) is the non-metallic component. Note. The name of the non-metallic component of a binary compound always ends in -ide.

In this unit you will learn how to work out and write chemical formulae of binary compounds.

turn over

Given below is a list of names of binary compounds and their chemical formulae. The formulae of the compounds have been analysed to show the pattern of chemical formulae. Study them carefully, using Data Sheet B.

COMPOUND	FORMULA	Metallic component	Combining power of metallic element Cp	Number of units of metallic element n	Total combining power of metallic units n x Cp	Non-metallic component	Combining power of non-metallic element Cp'	Number of units of non-metallic element n'	Total combining power of non-metallic units n' x Cp'
calcium chloride	$CaCl_2$	Ca	2	1	1 x 2 = 2	Cl	1	2	2 x 1 = 2
potassium iodide	KI	K	1	1	1 x 1 = 1	I	1	1	1 x 1 = 1
aluminium chloride	$AlCl_3$	Al	3	1	1 x 3 = 3	Cl	1	3	3 x 1 = 3
aluminium oxide	Al_2O_3	Al	3	2	2 x 3 = 6	O	2	3	3 x 2 = 6
aluminium nitride	AlN	Al	3	1	1 x 3 = 3	N	3	1	1 x 3 = 3
barium oxide	BaO	Ba	2	1	1 x 2 = 2	O	2	1	1 x 2 = 2
germanium oxide	GeO_2	Ge	4	1	1 x 4 = 4	O	2	2	2 x 2 = 4

From the above table you will notice that for a chemical formula to be balanced or correct, the total combining power of the metallic units must be equal to the total combining power of the non-metallic units in the compound.

The balancing is achieved by taking appropriate number of units of the metallic and non-metallic element. For example, in aluminium oxide aluminium has a combining power of three and oxygen has a combining power of two, therefore to balance the formula of aluminium oxide 2 units of aluminium and 3 units of oxygen are required.

turn over

From the above study of chemical formulae we can adopt a simple method for working out and writing a chemical formula.

i) Write down the symbols and the combining powers of the elements in the compound.

ii) Balance the combining powers of the metallic and the non-metallic component of the compound by taking the lowest ratio of units of the elements

The lowest ratio of units of the elements required for balancing the formula is equal to the ratio of the combining power of the non-metallic element to the combining power of the metallic element, or that ratio reduced to the simplest form.

Examples:

aluminium oxide

symbols of the elements	Al		O
combining powers	3		2
let the ratio of units of elements required to balance be	p	:	q

For the formula of aluminium oxide to be balanced the combining power of aluminium times p must be equal to the combining power of oxygen times q, that is, $3 \times p = 2 \times q$. Therefore the value of p and q must be 2 and 3, respectively. This is equal to the ratio of the combining power of oxygen to the combining power of aluminium. Hence, the formula of aluminium oxide is Al_2O_3

germanium oxide

symbols of the elements	Ge		O
combining powers	4		2
let the ratio of units of elements required to balance be	n	:	m

For the formula of germanium oxide to be balanced the combining power of germanium times n must be equal to the combining power of oxygen times m, that is, $4 \times n = 2 \times m$. Therefore, the value of n and m must be 1 and 2, respectively. This is equal to the ratio of the combining power of oxygen to the combining power of germanium 2:4 reduced to the simplest form 1:2. Hence, the formula of germanium oxide is GeO_2.

PART 2.

Given below is a list of names of binary compounds. Using the Data Sheet B and what you have found about the formula of binary compounds in Part 1, work out the chemical formulae of these compounds.

COMPOUND	Symbol of metallic element	Combining power of metallic element	Symbol of non-metallic element	Combining power of non-metallic element	Number of metallic element units required	Number of non-metallic element units required	FORMULA
magnesium nitride							
bismuth chloride							
strontium bromide							
antimony sulphide							
lithium oxide							
tin oxide							

PART 3.

A, B and C are three metallic elements having combining powers 1, 2 and 3, respectively.

X, Y and Z are three non-metallic elements having combining powers 1, 2 and 3 respectively.

Work out the formula of compounds formed between:

Components	Formula
A and Y	
C and X	
B and Z	
A and Z	
B and Y	
C and Y	

NAME ____________________ FORM __________

SCHOOL ____________________ DATE __________

A LEARNING PROGRAMME ON COMBINING POWER
AND CHEMICAL FORMULAE

(DISCOVERY VERSION)

UNIT 3

PROGRAMME COPY NUMBER ______

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INTRODUCTION

In this programme you will find the relationship between the combining power of an element and the position of the element in the Periodic Table and learn to work out chemical formulae. The combining power of an element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3 the elements X,Y and Z have combining powers of 1,2 and 3, respectively, since they combine with 1,2 and 3 units of chlorine.

The whole programme consists of FOUR learning units. You will do one unit per lesson over the next two weeks.

UNIT 1. The relationship between the combining power and the group number of an element.

UNIT 2. Chemical formulae of binary compounds.

UNIT 3. Combining powers of radicals and chemical formulae involving them.

UNIT 4. Combining powers of transition metals and chemical formulae involving them.

Each of the above units is divided into different parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

To help you work through these learning units, you are provided two Data Sheets. Data Sheet A is the PERIODIC TABLE of the elements and Data Sheet B gives the symbols and combining powers of some common elements and radicals.

How to work through each learning unit.

1. Place Data Sheet A and Data Sheet B where you can see them as you work through the unit.
2. Read the information given in each part of the unit carefully and consider what task you are required to complete.
3. For most parts of the unit you will have to examine the data sheets and enter the required information in the spaces provided.
4. Inspect the information you have as a whole and form a general idea or rule which can help you to do further exercises.
5. If you are unable to do a given task in the unit, proceed to the next.

You may find it helpful to know the Roman and Arabic numerials.

Roman numerials:	I	II	III	IV	V	VI	VII	VIII	IX	X
Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT 3. The combining power of radicals and formulae involving them.

PART 1.

Radicals are groups of elements that always stay combined together in chemical compounds, eg. the hydroxide group consisting of one unit of oxygen and one unit of hydrogen, symbol OH; the carbonate group consisting of one unit of carbon and three units of oxygen, symbol CO_3.

In writing chemical formulae, the symbol of the radical is considered as a single unit. Each radical has a specific combining power. When more than one unit of a radical is present in a chemical compound, they are represented in the formula using a bracket and a numerial. For example, the two units of nitrate, NO_3, in calcium nitrate are written as $Ca(NO_3)_2$.

In this unit you are going to find out how to work out combining power of radicals from compounds containing them and to work out chemical formulae involving radicals.

Given below is a list of names of compounds containing radicals and their formulae. Using Data Sheet B and what you have learned in Unit 2 (see summary sheet provided), analyse each formula and complete the table.

COMPOUND	FORMULA	Combining power of metallic element Cp	Number of units of metallic element n	Total combining power of metallic units n x Cp	Number of units of radical n'	Combining power of radical Cp'
calcium nitrate	$Ca(NO_3)_2$	2	1	1 x 2 = 2	2	
sodium carbonate	Na_2CO_3					
barium sulphate	$BaSO_4$					
aluminium hydroxide	$Al(OH)_3$	3	1	1 x 3 = 3	3	
calcium phosphate	$Ca_3(PO_4)_2$					
calcium hydrogencarbonate	$Ca(HCO_3)_2$					

From what you have noticed in the above table, can you suggest a way of working out the combining power of a radical given the formula of a compound containing it and the combining power of the metallic element? If so, state it.

___

___

___

PART 2.

Given below is a list of names of chemical compounds containing some other radicals. Using Data Sheet B and what you have found in Part 1, determine the combining power of the radicals present in the compounds.

COMPOUND	FORMULA	Combining power of metallic element Cp	Number of units of metallic element n	Total combining power metallic units T	Number of units of radical n'	Combining power of radical Cp'
calcium iodate	$Ca(IO_3)_2$					
sodium silicate	Na_2SiO_3					
barium chromate	$BaCrO_4$					
potassium dichromate	$K_2Cr_2O_7$					
sodium hydrogensulphate	$NaHSO_4$					
potassium permanganate	$KMnO_4$					

NAME ______________________________ FORM ____________

SCHOOL ____________________________ DATE ____________

A LEARNING PROGRAMME ON COMBINING POWER AND CHEMICAL FORMULAE

(EXPOSITORY VERSION)

UNIT 3

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY

1979/80

UNIVERSITY OF KEELE,

Department of Education.

INTRODUCTION

In this programme you will learn about the relationship between the combining power of an element and the position of the element in the Periodic Table and learn to work out chemical formulae.

The combining power of the element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3, the elements X, Y and Z have combining power of 1, 2 and 3, respectively, since they combine with 1, 2 and 3 units of chlorine.

The whole programme consists of FOUR learning units. You will do one unit per lesson over the next two weeks.

UNIT 1. The relationship between the combining power and the group number of an element.

UNIT 2. Chemical formulae of binary compounds.

UNIT 3. Combining power of radicals and chemical formulae involving them.

UNIT 4. Combining powers of transition metals and chemical formulae involving them.

Each of the above units is divided into parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

To help you to work through these learning units, you are provided with two Data Sheets. Data Sheet A is the PERIODIC TABLE of the elements, and Data Sheet B gives the symbols and combining powers of some common elements and radicals.

How to work through each learning unit.

1. Place Data Sheet A and Data Sheet B where you can see them as you work through the unit.
2. Read the information given in each part of the unit.
3. Study the general rule given and examine how it fits the information in the table provided.
4. Do the exercises, using the information in the Data Sheets provided and what you have learned in the unit.
5. If you are unable to do a particular exercise in the unit, proceed to the next exercise.

You may find it helpful to know the Roman and Arabic numerials.

Roman numerials:	I	II	III	IV	V	VI	VII	VIII	IX	X
Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

<u>UNIT 3.</u> The combining power of radicals and chemical formulae involving them.

<u>PART 1.</u>

Radicals are a group of elements that always stay combined together in chemical compounds. For example, the hydroxide group OH, consists of one unit of oxygen and one unit of hydrogen; the carbonate group CO_3, consista of one unit of carbon and three units of oxygen.

In writing chemical formulae a radical is considered as a single unit and each radical has a specific combining power. When more than one unit of a radical is present in a compound they are represented in the formula using a bracket and a numerial to denote the number of units. For example, the two units of nitrate group NO_3 in calcium nitrate are written as $Ca(NO_3)_2$.

In this unit you are going to learn how to determine the combining power of radicals from formulae of compounds containing them. Also, learn to work out and write chemical formulae involving radicals.

Study the table given below carefully with the help of Data Sheet B and what you have learned about chemical formula in Unit 2.

COMPOUND	FORMULA	Combining power of metallic element Cp	Number of units of metallic element n	Total combining power of metallic units n x Cp = T	Number of units of radical n'	Combining power of radical $\frac{T}{n'}$
calcium nitrate	$Ca(NO_3)_2$	2	1	1 x 2 = 2	2	$\frac{2}{2} = 1$
sodium carbonate	Na_2CO_3	1	2	2 x 1 = 2	1	$\frac{2}{1} = 2$
barium sulphate	$BaSO_4$	2	1	1 x 2 = 2	1	$\frac{2}{1} = 2$
aluminium hydroxide	$Al(OH)_3$	3	1	1 x 3 = 3	3	$\frac{3}{3} = 1$
calcium phosphate	$Ca_3(PO_4)_2$	2	3	3 x 2 = 6	2	$\frac{6}{2} = 3$
calcium hydrogencarbonate	$Ca(HCO_3)_2$	2	1	1 x 2 = 2	2	$\frac{2}{2} = 1$

From the above examples we can see that <u>the combining power of a radical can be obtained from a given formula containing it by dividing the total combining power of the metallic component of the compound by the number of units of the radical in the compound.</u>

For example, in calcium phosphate $Ca_3(PO_4)_2$, the combining power of the phosphate group is 3. This value is obtained by dividing 6 by 2, where 6 is the total combining power of the calcium units and 2 is the number of phosphate units in the compound.

PART 2.

Given below is a list of names of chemical compounds containing some other radicals. Using Data Sheet B and what you have found in Part 1, determine the combining power of the radicals present in the compounds.

COMPOUND	FORMULA	Combining power of metallic element Cp	Number of units of metallic element n	Total combining power metallic units T	Number of units of radical n'	Combining power of radical Cp'
calcium iodate	$Ca(IO_3)_2$					
sodium silicate	Na_2SiO_3					
barium chromate	$BaCrO_4$					
potassium dichromate	$K_2Cr_2O_7$					
sodium hydrogensulphate	$NaHSO_4$					
potassium permanganate	$KMnO_4$					

PART 3.

Given below is a list of names of chemical compounds. Using Data Sheet B, and what you have learned about chemical formulae in Unit 2, work out the chemical formula of the compounds.

COMPOUND	Symbol of metallic element	Combining power of metallic element	Symbol of radical	Combining power of radical	FORMULA
calcium hydroxide					
potassium hydogenphosphate					
barium nitrate					
magnesium carbonate					
aluminium phosphate					
sodium chromate					

PART 4.

A, B and C are three metallic elements having combining powers 1, 2 and 3, respectively.

XO_3, YO_4 and ZO_4 are three radicals having combining powers 1, 2 and 3, respectively.

Work out the formulae of compounds formed between:

Components	Formula
A and XO_3	
B and ZO_4	
C and YO_4	
A and YO_4	
B and XO_3	
C and ZO_4	

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A LEARNING PROGRAMME ON COMBINING POWER AND CHEMICAL FORMULAE

(DISCOVERY VERSION)

UNIT 4

PROGRAMME COPY NUMBER ________

A. LOURDUSAMY
1979/80

UNIVERSITY OF KEELE,
Department of Education.

INTRODUCTION

In this programme you will find the relationship between the combining power of an element and the position of the element in the Periodic Table and learn to work out chemical formulae. The combining power of an element, also sometimes called the valency of the element, is the number of units of another element with a combining power of one with which the element will combine to form a chemical compound. Chlorine has a combining power of one. In compounds like XCl, YCl_2 and ZCl_3 the elements X,Y and Z have combining powers of 1,2 and 3, respectively, since they combine with 1,2 and 3 units of chlorine.

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UNIT 1. The relationship between the combining power and the group number of an element.

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Each of the above units is divided into different parts, each of which is numbered for easy reference. Some instructions are given by reference to part numbers.

To help you work through these learning units, you are provided two Data Sheets. Data Sheet A is the PERIODIC TABLE of the elements and Data Sheet B gives the symbols and combining powers of some common elements and radicals.

How to work through each learning unit.

1. Place Data Sheet A and Data Sheet B where you can see them as you work through the unit.
2. Read the information given in each part of the unit carefully and consider what task you are required to complete.
3. For most parts of the unit you will have to examine the data sheets and enter the required information in the spaces provided.
4. Inspect the information you have as a whole and form a general idea or rule which can help you to do further exercises.
5. If you are unable to do a given task in the unit, proceed to the next.

You may find it helpful to know the Roman and Arabic numerials.

Roman numerials:	I	II	III	IV	V	VI	VII	VIII	IX	X
Arabic numerials:	1	2	3	4	5	6	7	8	9	10

IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT 4. The combining power of transition metals and formulae involving them.

PART 1.

The group of elements in the middle of the Periodic Table between Group II and Group III are called transition metals. Transition metals behave differently from other metals when they form compounds.

In this unit you are going to find out about the combining behaviour of transition metals and work out chemical formulae of transition metal compounds.

Given below is a list of names of transition metal compounds. Using Data Sheet B and what you have learned about the formula of binary compounds, analyse the formula of the transition metal compounds given and complete the table.

COMPOUND	FORMULA	Number of units of non-metallic element n'	Combining power of non-metallic element Cp'	Total combining power of non-metallic units T	Number of units of transition metal n	Combining power of transition metal $\frac{T}{n}$
iron(II) chloride	$FeCl_2$	2	1	2 x 1 = 2	1	
iron(III) chloride	$FeCl_3$					
chromium(II) oxide	CrO					
chromium(III) oxide	Cr_2O_3					
chromium(VI) oxide	CrO_3					
manganese(II) oxide	MnO					
manganese(III) oxide	Mn_2O_3	3	2	3 x 2 = 6	2	
manganese(IV) oxide	MnO_2					
copper(I) oxide	Cu_2O					
copper(II) oxide	CuO					

i) In what way does the transition metals differ from the other metals in their combining behaviour?

____

ii) Do you notice any difference in the way we write the names of transition metal compounds? If so, state it.

____

PART 2.

Using Data Sheet B and what you have noticed in Part 1 about the combining behavior of transition metals, work out the chemical formula of the following transition metal compounds.

COMPOUND	Symbol of transition metal	Combining power of transition metal	Symbol of non-metallic component	Combining power of non-metallic component	Number of transition metal units required	Number of non-metallic unit required	FORMULA
gold(III) chloride							
vanadium(V) oxide							
iron(III) hydroxide							
manganese(II) nitrate							
chromium(III) sulphate							
cobalt(III) nitrate							

PART 3.

Given below is a list of chemical formulae of transition metal compounds. Using Data Sheet B and what you have noticed about the names of transition metal compounds, analyse each of the formula and write down the chemical name of the compound.

Formula	Combining power of transition metal in compound	Chemical name of compound
$Fe_2(SO_4)_3$		
$Hg(NO_3)_2$		
TiI_4		
$CuCO_3$		
$Co(OH)_2$		
$FeCO_3$		
$Co_2(SO_4)_3$		
V_2O_3		
$TiCl_2$		
Cu_2S		
WCl_5		
VCl_4		
WO_3		

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IF YOU ARE READY, TURN OVER THE PAGE AND WORK THROUGH THE GIVEN UNIT.

UNIT 4. The combining power of transition metals and formulae involving them.

PART I.

Look at the Data Sheet A, the Periodic Table of elements. The group of elements in the middle of the table betweem Group II and Group III are called the transition metals. Transition metals behave quite differently from other metals when they form compounds.

In this unit you are going to learn about the combining behaviour of transition metals and work out chemical formula involving them.

Study the examples given below carefully and look for any peculiarity in the combining behavior of the transition metals and the way in which we write the name of a transition metal compound.

COMPOUND	FORMULA	Combining Power of non-metallic element Cp	Number of units of non-metallic element n	Total combining power of non-metallic units n x Cp = T	Number of units of transition metal n'	Combining Power of transition metal $\frac{T}{n'}$
iron(II) chloride	$FeCl_2$	1	2	2 x 1 = 2	1	$\frac{2}{1} = 2$
iron(III) chloride	$FeCl_3$	1	3	3 x 1 = 3	1	$\frac{3}{1} = 3$
chromium(II) oxide	CrO	2	1	1 x 2 = 2	1	$\frac{2}{1} = 2$
chromium(III) oxide	Cr_2O_3	2	3	3 x 2 = 6	2	$\frac{6}{2} = 3$
chromium(VI) oxide	CrO_3	2	3	3 x 2 = 6	1	$\frac{6}{1} = 6$
manganese(II) oxide	MnO	2	1	1 x 2 = 2	1	$\frac{2}{1} = 2$
manganese(III) oxide	Mn_2O_3	2	3	3 x 2 = 6	2	$\frac{6}{2} = 3$
manganese(IV) oxide	MnO_2	2	2	2 x 2 = 4	1	$\frac{4}{1} = 4$

From the examples given above we can see that

i) a transition metal has more than one combining power in its compounds, i.e, the transition metals exhibit variable combining power in their compounds. For example, iron has combining powers 2 and 3 in its compounds; chromium has combining powers 2, 3 and 6 in its compounds.

ii) in writing the name of a transition metal compound the combining power of the metal in that compound is indicated in a bracket using Roman numerial. For example, in manganese(IV) oxide (IV) indicates the combining power of manganese in that oxide.

PART 2.

Using Data Sheet B and what you have noticed in Part 1 about the combining behavior of transition metals, work out the chemical formula of the following transition metal compounds.

COMPOUND	Symbol of transition metal	Combining power of transition metal	Symbol of non-metallic component	Combining power of non-metallic component	Number of transition metal units required	Number of non-metallic unit required	FORMULA
gold(III) chloride							
vanadium(V) oxide							
iron(III) hydroxide							
manganese(II) nitrate							
chromium(III) sulphate							
cobalt(III) nitrate							

PART 3.

Given below is a list of chemical formulae of transition metal compounds. Using Data Sheet B and what you have noticed about the names of transition metal compounds, analyse each of the formula and write down the chemical name of the compound.

Formula	Combining power of transition metal in compound	Chemical name of compound
$Fe_2(SO_4)_3$		
$Hg(NO_3)_2$		
TiI_4		
$CuCO_3$		
$Co(OH)_2$		
$FeCO_3$		
$Co_2(SO_4)_3$		
V_2O_3		
$TiCl_2$		
Cu_2S		
WCl_5		
VCl_4		
WO_3		

DATA SHEET A

The Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** HYDROGEN 1																	2 **He** HELIUM 4
3 **Li** LITHIUM 7	4 **Be** BERYLLIUM 9											5 **B** BORON 11	6 **C** CARBON 12	7 **N** NITROGEN 14	8 **O** OXYGEN 16	9 **F** FLUORINE 19	10 **Ne** NEON 20
11 **Na** SODIUM 23	12 **Mg** MAGNESIUM 24	Transition Metals										13 **Al** ALUMINIUM 27	14 **Si** SILICON 28	15 **P** PHOSPHORUS 31	16 **S** SULPHUR 32	17 **Cl** CHLORINE 35·5	18 **Ar** ARGON 40
19 **K** POTASSIUM 39	20 **Ca** CALCIUM 40	21 **Sc** SCANDIUM 45	22 **Ti** TITANIUM 48	23 **V** VANADIUM 51	24 **Cr** CHROMIUM 52	25 **Mn** MANGANESE 55	26 **Fe** IRON 56	27 **Co** COBALT 59	28 **Ni** NICKEL 59	29 **Cu** COPPER 63·5	30 **Zn** ZINC 65	31 **Ga** GALLIUM 70	32 **Ge** GERMANIUM 72·5	33 **As** ARSENIC 75	34 **Se** SELENIUM 79	35 **Br** BROMINE 80	36 **Kr** KRYPTON 84
37 **Rb** RUBIDIUM 85·5	38 **Sr** STRONTIUM 88	39 **Y** YTTRIUM 89	40 **Zr** ZIRCONIUM 91	41 **Nb** NIOBIUM 93	42 **Mo** MOLYBDENUM 96	43 **Tc** TECHNETIUM	44 **Ru** RUTHENIUM 101	45 **Rh** RHODIUM 103	46 **Pd** PALLADIUM 106	47 **Ag** SILVER 108	48 **Cd** CADMIUM 112	49 **In** INDIUM 115	50 **Sn** TIN 119	51 **Sb** ANTIMONY 122	52 **Te** Tellurium 128	53 **I** Iodine 127	54 **Xe** 131
55 **Cs** CAESIUM 133	56 **Ba** BARIUM 137	57 **La** LANTHANUM 137	* 72 **Hf** HAFNIUM 178·5	73 **Ta** TANTALUM 181	74 **W** TUNGSTEN 184	75 **Re** RHENIUM 186	76 **Os** OSMIUM 190	77 **Ir** IRIDIUM 192	78 **Pt** PLATINUM 195	79 **Au** GOLD 197	80 **Hg** MERCURY 201	81 **Tl** THALLIUM 204	82 **Pb** LEAD 207	83 **Bi** BISMUTH 209	84 **Po** POLONIUM	85 **At** ASTATINE	86 **Rn** RADON
87 **Fr** FRANCIUM	88 **Ra** RADIUM 226	89 **Ac** ACTINIUM	+														

*	58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm**	62 **Sm** 150	63 **Eu** 152	64 **Gd** 157	65 **Tb** 159	66 **Dy** 162·5	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173	71 **Lu** 175
+	90 **Th** 232	91 **Pa** 231	92 **U** 238	93 **Np** 237	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lw**

DATA SHEET B

Table of Combining Power of Elements

The table below gives the symbol and the combining power of some common elements and groups of atoms(radicals). The names of the elements are listed in alphabetical order in this table for easy reference.

You will have to fill in the missing data after working through each learning unit.

ELEMENT	Symbol	Combining power	ELEMENT	Symbol	Combining power
Aluminium	Al	3	Lithium	Li	1
Antimony	Sb		Magnesium	Mg	
Barium	Ba	2	Manganese	Mn	
Beryllium	Be	2	Mercury	Hg	
Bismuth	Bi	3	Nickel	Ni	
Boron	B		Nitrogen (nitride)	N	3
Bromine (bromide)	Br	1	Osmium	Os	
Caesium	Cs		Oxygen (oxide)	O	2
Calcium	Ca	2	Phosphous (phosphide)	P	
Carbon	C	4	Platinium	Pt	
Chlorine (chloride)	Cl	1	Potassium	K	
Chromium	Cr		Radium	Ra	
Cobalt	Co		Rubidium	Rb	1
Copper	Cu		Selenium	Se	
Fluorine (fluoride)	F		Silicon	Si	
Germanium	Ge	4	Silver	Ag	1
Gold	Au		Sodium	Na	1
Hydrogen (hydride)	H	1	Strontium	Sr	
Iodine (iodide)	I		Sulphur (sulphide)	S	2
Iron	Fe		Tin	Sn	
Lead	Pb		Titanium	Ti	
			Tungsten	W	
			Vanadium	V.	

DATA SHEET B

The Combining Power of Radicals

RADICAL	Symbol	Combining Power
acetate	CH_3COO	1
carbonate	CO_3	
chromate	CrO_4	
dichromate	Cr_2O_7	
hydrogencarbonate	HCO_3	
hydrogenphosphate	HPO_4	2
hydrogensulphate	HSO_4	
hydroxide	OH	
iodate	IO_3	
nitrate	NO_3	
permanganate	MnO_4	
phosphate	PO_4	
silicate	SiO_3	
sulphate	SO_4	

Summary Sheet 1

*1. The combining power of an element present in Group I, II, III or IV of the Periodic Table is equal to its group number.

For example, barium is in Group II, therefore its combining power is equal to 2; aluminium is in Group III, therefore its combining power is equal to 3.

*2. The combining power of an element present in Group V, VI or VII of the Periodic Table is equal to eight minus the group number of the element.

For example, phosphorus is in Group V, therefore its combining power is equal to 8 - 5 = 3; sulphur is in Group VI, therefore its combining power is equal to 8 - 6 = 2.

Summary Sheet 2

For a chemical formula to be balanced or correct, the total combining power of the metallic units must be equal to the total combining power of the non-metallic units in the compound.

The combining powers are balanced by taking the correct number of units of the elements present in the compound.

For example, in aluminium oxide Al_2O_3, the combining power of aluminium is 3 and the combining power of oxygen is 2. The formula is balanced by taking 2 units of aluminium and 3 units of oxygen. Hence, the total combining power of the metallic units is equal to 2 units of aluminium x its combining power 3 = 6 and the total combining power of the non-metallic units is equal to 3 units of oxygen x its combining power 2 = 6.

Based on the above information we can adopt a simple method for working out and writing a chemical formula.

i) Write down the symbols and the combining powers of the elements in the compound.

ii) Balance the combining powers of the metallic and the non-metallic component of the compound by taking the lowest ratio of units of the elements in the compound.

The lowest ratio of units of the elements required for balancing the formula is equal to the ratio of the combining power of the non-metallic element to the combining power of the metallic element, or that ratio reduced to the simplest form.

Example 1. aluminium oxide

symbols of the elements	Al O
combining powers	3 2
let the ratio of units of elements required be	p : q

For the formula of aluminium oxide to be balanced the combining power of aluminium times p must be equal to the combining power of oxygen times q, that is, 3 x p = 2 x q. Therefore, the value of p and q must 2 and 3, respectively. This is equal to the ratio of the combining power of oxygen to the combining power of aluminium.

Hence, the formula of aluminium oxide is Al_2O_3.

Example 2. germanium oxide

symbols of the elements	Ge O
combining powers	4 2
let the ratio of units of elements required be	n : m

For the formula of germanium oxide to be balanced the combining power of germanium times n must be equal to the combining power of oxygen times m, that is, 4 x n = 2 x m. Therefore, the value of n and m must be 1 and 2, respectively. This is equal to the ratio of the combining power of oxygen to the combining power of germanium 2:4 reduced to the simplest form 1:2.

Hence, the formula of germanium oxide is GeO_2.

Summary Sheet 3

*1. A radical is a group of elements that always stay combinined together in a compound, e.g. the carbonate group, CO_3; the sulphate group, SO_4.

Each radical has a specific combining power. The combining power of a radical can be worked out from a given formula containing it by dividing the total combining power of the metallic units by the number of units of the radical present in the formula of the compound.

For example, the combining power of the phosphate group, (PO_4) in calcium phosphate, $Ca_3(PO_4)_2$ can be worked out as follows:

combining power of the metallic element	= 2
number of units of the metallic element	= 3
total combining power of metallic units	= 3 x 2 = 6
number of units of phosphate group	= 2
combining power of phosphate group	$= \frac{6}{2} = 3$

*2. Chemical formulae of compounds involving radicals can be worked out on the same principle as explained in Summary Sheet 2, for binary compounds.

Example: potassium chromate

symbols	K		CrO_4
combining powers	1		2
ratio of units required for balanced formula	2	:	1

Hence, the formula of potassium chromate is K_2CrO_4

Summary Sheet 4

*1. The transition metals show variable combining powers in their compounds.

For example, iron has combining powers 2 and 3 in its compounds; chromium has combining powers 2, 3 and 6 in its compounds.

*2. In writing the name of a transition metal compound, the combining power of the metal in that compound is indicated in a bracket using the Roman numerial.

For example, in manganese (IV) oxide, (IV) indicates the combining power of manganese in that oxide. Hence, the formula of manganese(IV) oxide is MnO_2.

APPENDIX C

Tables of item facilities and item-total score correlations for items in the various cognitive style tests and preference inventory.

TABLE C.1 ITEM FACILITIES AND ITEM-TOTAL SCORE CORRELATIONS FOR "PRESENT" ITEMS, CONCEALED SHAPES TEST (N=344).

Item Number	Item Facility	Item-total Score Correlation	Item Number	Item Facility	Item-total Score Correlation
1	0.986	0.090	49	0.692	0.225
2	0.765	0.305	50	0.567	0.269
4	0.959	0.245	54	0.817	0.218
5	0.042	0.135	55	0.892	0.306
6	0.477	0.152	57	0.939	0.151
7	0.872	0.227	59	0.427	0.309
8	0.855	0.374	60	0.936	0.196
10	0.985	0.145	64	0.465	0.330
12	0.945	0.227	65	0.930	0.226
13	0.480	0.340	68	0.811	0.384
14	0.942	0.172	70	0.511	0.186
17	0.209	0.242	71	0.692	0.306
18	0.974	0.078	76	0.590	0.406
21	0.834	0.234	77	0.894	0.411
23	0.701	0.324	78	0.848	0.340
26	0.942	0.222	79	0.788	0.356
28	0.622	0.322	80	0.837	0.265
30	0.828	0.389	81	0.849	0.258
34	0.936	0.289	82	0.773	0.261
36	0.811	0.357	86	0.732	0.232
39	0.895	0.206	90	0.701	0.433
40	0.765	0.358	91	0.244	0.319
41	0.451	0.245	92	0.863	0.296
42	0.805	0.066	94	0.555	0.071
43	0.892	0.204	96	0.358	0.308
45	0.459	0.278			

TABLE C.2 ITEM FACILITIES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE "ABSENT" ITEMS, CONCEALED SHAPES TEST (N=344).

Item Number	Item Facility	Item-total Score Correlation	Item Number	Item Facility	Item-total Score Correlation
3	0.968	0.117	52	0.695	0.314
9	0.483	0.108	53	0.939	0.055
11	0.959	0.122	56	0.974	0.323
15	0.602	-0.238	58	0.840	0.323
16	0.747	0.298	61	0.663	0.379
19	0.933	0.259	62	0.837	0.183
20	0.942	0.221	63	0.968	0.187
22	0.919	0.151	66	0.776	0.260
24	0.834	0.282	67	0.907	0.389
25	0.625	0.290	69	0.939	0.178
27	0.619	0.325	72	0.933	0.396
29	0.907	0.224	73	0.855	0.272
31	0.834	0.274	74	0.892	0.308
32	0.416	0.292	75	0.555	0.415
33	0.933	0.143	83	0.913	0.208
35	0.921	0.183	84	0.948	0.236
37	0.913	0.133	85	0.831	0.317
38	0.849	0.190	87	0.866	0.331
44	0.924	0.232	88	0.683	0.351
46	0.439	0.228	89	0.831	0.426
47	0.634	0.385	93	0.813	0.287
48	0.927	0.189	95	0.761	0.273
51	0.799	0.279			

TABLE C.3 ITEM FACILITIES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE "PRESENT" ITEMS, HIDDEN FIGURES TEST (N=124).

Item Number	Item Facility	Item-total Score Correlation	Item Number	Item Facility	Item-total Score Correlation
3	0.629	0.236	28	0.855	0.235
6	0.581	0.176	32	0.532	0.337
7	0.798	0.074	34	0.790	0.230
13	0.718	0.217	37	0.290	0.111
17	0.726	0.235	39	0.508	0.312
18	0.750	0.200	41	0.258	0.184
21	0.387	0.165	43	0.677	0.286
23	0.968	0.202	44	0.548	0.230
27	0.677	0.128	48	0.395	0.201

TABLE C.4 ITEM FACILITIES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE "ABSENT" ITEMS, HIDDEN FIGURES TEST (N=124).

Item Number	Item Facility	Item-total Score Correlation	Item Number	Item Facility	Item-total Score Correlation
1	0.903	0.099	24	0.613	0.223
2	0.863	0.188	25	0.935	0.469
4	0.863	0.230	26	0.871	0.510
5	0.218	-0.116	29	0.903	0.530
8	0.944	0.228	30	0.903	0.505
9	0.919	0.301	31	0.823	0.534
10	0.806	0.147	33	0.855	0.574
11	0.871	0.324	35	0.839	0.468
12	0.750	0.232	36	0.823	0.483
14	0.944	0.307	38	0.871	0.510
15	0.323	0.053	40	0.694	0.517
16	0.935	0.356	42	0.874	0.456
19	0.847	0.445	45	0.726	0.536
20	0.871	0.318	46	0.645	0.393
22	0.969	0.324	47	0.645	0.487

TABLE C.5 ITEM MEAN SCORES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE RELATIONAL SCALE ITEMS (N=189).

Item Number	Item Mean Score (Max=3)	Item-total Score Correlation	Item Number	Item Mean Score (Max=3)	Item-total Score Correlation
1	1.76	0.177	13	1.60	0.244
2	2.05	0.370	14	1.89	0.517
3	1.29	0.213	15	1.85	0.456
4	2.02	0.278	16	1.60	0.451
5	1.54	0.362	17	1.76	0.455
6	1.92	0.374	18	2.14	0.120
7	2.05	0.315	19	1.65	0.411
8	1.41	0.297	20	1.86	0.519
9	1.77	0.280	21	1.93	0.323
10	1.79	0.338	22	1.61	0.453
11	2.67	0.212	23	1.73	0.388
12	2.08	0.268	24	1.68	0.283

TABLE C.6 ITEM MEAN SCORES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE DESCRIPTIVE SCALE ITEMS (N=189).

Item Number	Item Mean Score (Max=3)	Item-total Score Correlation	Item Number	Item-Mean Score (Max=3)	Item-total Score Correlation
1	1.60	0.229	13	1.76	0.163
2	1.55	0.276	14	1.74	0.293
3	2.21	0.107	15	1.55	0.248
4	1.22	0.272	16	1.91	0.311
5	2.08	0.054	17	2.25	0.257
6	1.37	0.156	18	1.40	0.344
7	1.37	0.338	19	1.79	0.418
8	2.01	0.244	20	1.56	0.278
9	1.75	0.283	21	1.54	0.378
10	1.37	0.316	22	1.76	0.482
11	1.53	0.147	23	1.56	0.347
12	1.35	0.373	24	1.63	0.388

TABLE C.7 ITEM MEAN SCORES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE INFERENTIAL SCALE ITEMS (N=189).

Item Number	Item Mean Score (Max=3;Min=1)	Item-total Score Correlation	Item Number	Item Mean Score (Max=3;Min=1)	Item-total Score Correlation
1	2.64	0.194	13	2.58	0.535
2	2.37	0.350	14	2.37	0.475
3	2.47	0.326	15	2.57	0.482
4	2.73	0.292	16	2.46	0.486
5	2.37	0.327	17	1.99	0.128
6	2.65	0.293	18	2.46	0.300
7	2.58	0.239	19	2.56	0.403
8	2.57	0.284	20	2.59	0.398
9	2.47	0.312	21	2.50	0.434
10	2,84	0.232	22	2.63	0.411
11	1.74	0.020	23	2.71	0.443
12	2.56	0.314	24	2.65	0.390

TABLE C.8 ITEM MEAN SCORES AND ITEM-TOTAL SCORE CORRELATIONS FOR THE FLUENCY SCALE AND FLEXIBILITY SCALE ITEMS (N=249).

	Fluency Scale		Flexibility Scale	
Item	Item Mean Score	Item-total Score Correlation	Item Mean Score	Item-total Score Correlation
Newspaper	7.38	0.474	5.01	0.470
Brick	5.33	0.626	3.27	0.451
Paper Clip	3.59	0.621	2.59	0.479
Tin Can	4.77	0.568	3.04	0.468
Cork	3.76	0.628	2.65	0.463
Blanket	5.02	0.552	3.70	0.515

TABLE C.9 MEAN RESPONSE TIMES, MEAN ERROR SCORES, STANDARD DEVIATIONS AND ITEM-TOTAL SCORE CORRELATIONS FOR REFLECTIVITY-IMPULSIVITY ITEMS (N=78).

	Response Time Scale			Error Score Scale		
Item	Mean Response Time	Std. Dev.	Item-total Score Correl. Coefficient	Mean Error Score	Std. Dev.	Item-total Score Correl. Coefficient
1	12.35	9.01	0.605	0.56	0.89	0.043
2	9.14	4.80	0.547	0.26	0.51	0.346
3	11.03	6.45	0.767	0.71	0.75	-0.039
4	15.96	11.78	0.732	0.49	0.73	0.243
5	11.04	7.06	0.719	0.31	0.61	0.193
6	11.32	6.33	0.689	0.22	0.45	0.104
7	8.42	3.92	0.685	0.09	0.29	0.308
8	15.11	9.64	0.754	0.41	0.65	0.371
9	16.38	11.83	0.834	0.85	0.98	0.046
10	19.58	17.87	0.820	1.10	1.22	0.246
11	18.97	13.45	0.707	0.24	0.56	0.072
12	10.31	5.29	0.709	0.44	0.71	0.137
13	15.49	11.79	0.818	0.58	0.69	0.140
14	14.92	9.35	0.784	0.78	0.98	0.152
15	9.89	5.44	0.637	0.15	0.45	0.423
16	11.90	6.12	0.737	0.32	0.52	0.409
17	13.13	9.02	0.853	0.70	0.76	0.235
18	14.06	9.16	0.829	0.37	0.72	0.300
19	15.87	10.75	0.826	0.36	0.68	0.350
20	12.13	7.37	0.727	0.54	1.70	0.402

TABLE C.10 ITEM-TOTAL SCORE CORRELATIONS FOR THE ITEMS IN EASE/DIFFICULTY SCALE AND ENJOYMENT/DISLIKE SCALE IN RELATION TO LEARNING BY DISCOVERY AND LEARNING FROM EXPOSITORY (N=275).

Scale	Item	Learning By Discovery Item-total Score Correl. Coefficient	Learning From Exposition Item-total Score Correl. Coefficient
Ease/ Difficulty	Easy/Difficult	0.754	0.831
	Simple/Complicated	0.747	0.818
	Fast/Slow	0.606	0.778
	Clear/Vague	0.615	0.735
	Undemanding/Demanding	0.173	0.293
	Straightforward/ Confusing	0.699	0.767
Enjoyment/ Dislike	Exciting/Dull	0.690	0.683
	Interesting/Boring	0.777	0.765
	Enjoyable/Tiresome	0.688	0.716
	Challenging/ Unchallenging	0.490	0.424
	Useful/Useless	0.595	0.506
	Efficient/Inefficient	0.511	0.417