THE INFLUENCE OF VARIOUS LEARNING STYLES ON PRACTICAL PROBLEM-SOLVING IN CHEMISTRY IN SCOTTISH SECONDARY SCHOOLS

by

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TO MY PARENTS

"MY LORD! BESTOW ON THEM THY
MERCY EVEN AS THEY CHERISHED
ME IN CHILDHOOD"

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CONTENTS

CHAPTER THREE

Approaches Towards Practical Investigations in Science - Practical Problem-Solving in Chemistry

CHAPTER FOUR

The Methodology which is Employed in Order to Measure the Pupils' Psychological Factors

CHAPTER FIVE

Possible Correlations between Psychological Factors Used in the Present Study

CHAPTER SIX

Mini-Projects in Chemistry: Evaluation and Pupils' Performance

CHAPTER SEVEN

The Relationships between Mini-Projects Attainments and Various Psychological Factors Used in the Study

CHAPTER EIGHT

Conclusions and Discussion

ABSTRACT

This thesis is devoted to focussing on the influence of various learning styles and psychological factors on the performance of school pupils in some creative practical problem-solving tasks in chemistry which are called the Mini-Projects at the bench. These projects have been selected for the research as they are believed to be capable of generating and developing a great deal of motivation and involvement in chemistry.

217 Pupils at Standard Grade Chemistry (age 15-16) have participated in the empirical part of this research and have been selected from five secondary schools in the Central Region of Scotland.

During the period of the study, the sample of pupils was subjected to some psychological tests in order to assign their Field-Dependent/Field-Independent and Convergent/Divergent learning styles as well as their Motivational Patterns or Preferences.

It was found throughout the research that the most effective combination of learning styles which has emerged from the interacting picture of all the psychological factors used in the research, are those of field-independent/divergent/curious-achiever styles in performing practical problem-solving in chemistry (pupil-centred) such as the mini-projects. On the other hand, the combination of field-dependent/convergent/conscientious-social styles could lessen achievement in the mini-projects. Moreover, when the mean scores were calculated for the various groups of pupils with various learning styles, the curious groups were found to be the best while the conscientious groups were found to be the worst. All these findings have been combined to form a model which emerges at the end of the present thesis. The findings demonstrate that the field-dependent/field-independent factor is the most effective in influencing performance in the mini-projects, the motivation factor is second and finally the convergent/divergent factor takes the third position.

CHAPTER ONE

AN INTRODUCTION OF SOME PSYCHOLOGICAL ELEMENTS INVOLVED IN A *PREDICTIVE THEORY* IN SCIENCE EDUCATION BASED UPON AN *INFORMATION PROCESSING MODEL*

1.1 Introduction

During his M.Sc. study[1], the researcher focussed his research on a *Predictive Theory for Science Education*[2] based upon an *Information Processing Model*. The common theme of the model evolved through the idea of how input information is stored and processed inside the human mind and how a response to this comes into existence.

This chapter is aimed to operate as a bridge between the researcher's previous work (the M.Sc. study) and his present work (the Ph.D. study).

Different psychological factors related to the information processing model were studied in the previous research aiming to find out their effectiveness on the learning and teaching of chemistry at secondary and tertiary levels of chemical education.

It seemed evident that various other factors would affect subjects in their learning of science and in particular of chemistry. Practical work in chemistry will be used in this research as an element of chemistry science. Using the two disciplines of psychology and chemistry, but with a continued emphasis upon chemistry, the researcher intends to make these disciplines work together, play off against each other, cohere, or disagree in an attempt to encourage new meanings, discover fresh signs and messages for science education.

In brief, the hypotheses which the present study has evolved around were shaped by certain evidence which became apparent during the researcher's M.Sc. studies. The researcher became aware that there were some learners who, while being classified as less able learners according to their achievement in conventional chemistry examinations, could still perform to a satisfactory level in other kinds of more practical problem-solving tests in chemistry. Indeed, at times they displayed a greater aptitude in these areas than more generally able learners.

1.2 The Holding/Thinking Space (Working Memory Space) in the Predictive Theory

According to the predictive information processing model, there is a part in the brain where the input information is held, organised, shaped and worked upon before it is stored in long-term memory. This area is designated the *working memory* or *holding/thinking space* or the *X-space*. The functions of this area have been subjected to many studies.

Holding/thinking space is a limited space[3] in which consciousness exists. Baddeley (1986)[4] defines this space as a busy area of the brain into which selected sensory input comes into contact with material from long-term memory and undergoes a variety of processes.

Ultimately, new input information may be forgotten or be found difficult to recall again because it is irrelevant or linked to something which is not substantial. Other input may be stored in long-term memory and used in further procedures. Ausubel (1978)[5] refers to these later two processes as rote and meaningful learning respectively. A model which may represent the thinking processes in the human's mind is shown in figure 1.1. Such a model has been proposed at the Centre for Science Education/Glasgow University .

In literature, this space is more often designated *working memory*[4], M-space[6], or M-power[7]. The limitation of working memory space may be circumvented to some extent by using strategies e. g. schemata, tricks, techniques and previous knowledge to group the input into manageable clusters or chunks.

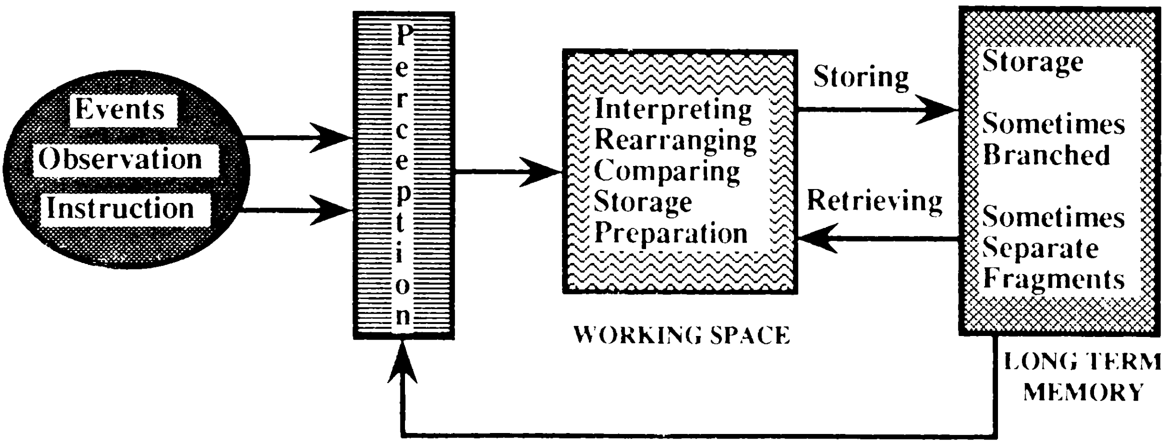

Figure 1.1 A model represents the thinking processes according to the predictive theory.

In the previous work (the M.Sc. study)[1], subjects were divided into three categories of high, medium and low capacity according to their achievements in particular psychological tests which measured the subjects' working memory capacity (holding/thinking space).

The researcher's previous study was intended to analyse the load of any chemistry question on subjects' mental capacities, specially during conventional chemistry examinations, in both secondary and tertiary levels of education. The predictive model[2] suggested calculating the number of thought steps involved in any particular question for the least sophisticated subject. The model used a term Z-demand to represent the number of thought steps which is related to the size of the input load on the human memory.

This assumption of the predictive model was originally related to Miller's (1956) proposal[8] which has gained wide acceptance: Miller suggested that short-term capacity is about 7 ± 2 chunks. A chunk is a word, letter or digit which describes a familiar item or unit.

It is apparent from previous work [1] in solving chemical problems that the subject would fail if the complexity of the task (Z-demand) exceeded his X-space. He or she may perform well until the demand of the question exceeded his or her X-space at which point a rapid and sudden decline in performance may be witnessed. The rapid fall in performance has been well substantiated in Pascual-Leone (1969)[9] and Scardamalia (1977)[10] studies as well as several other recent studies[11, 12].

Surprisingly, some subjects operated well even when the complexity (Z-demand) exceeded their X-space. These were interviewed and found to have some strategies like schema, tricks, techniques or previous knowledge which had been employed enabling them to group the input into manageable clusters or chunks and to perform well beyond their independently measured X-space.

It was observed[1] that the ability of high X-space subjects to survive high demand questions seems to be the greatest, therefore, the last subject who may fail in the highest demand question may be assumed to belong the category of high X-space subjects.

1.3 The Human Systems for Separating Relevant from Irrelevant Information

Because working memory space is of limited capacity, it is rational to assume that there is a system in the brain (controlled by long-term memory) which operates as a filter for selecting some of the input and ignoring the rest. Presumably, things which are selected are deemed to be relevant, important or interesting. This system requires some already established concept or structure which, for a first time learner, may not exist[13].

It is found that some subjects have difficulty in separating relevant information or 'signal'[14] from irrelevant information or 'noise'. For first time learners, all the information presented to them will seem to be important. Until they have a good grasp on the material and its concepts they cannot discriminate between the vital things to learn and the peripheral things. In the process of teaching a lot of peripheral material is given by the teacher, often unconsciously.

In psychology, a cognitive style is recognised called *Field-Dependence* (at one end) and *Field-Independence* (at the other end of a spectrum)[15, 16]. Field-dependent people are particularly prone to be influenced by incidental information and have difficulty in separating 'noise' from 'signal' in any situation. Field-independent people are better at getting to the nub of a situation and ignoring the incidentals.

When this is linked to the idea of a limited working memory space an interesting relationship is likely to emerge. The predictive model[2] enables us to raise hypotheses as follows:

I - If a subject is of low working memory capacity and field-dependent his performance will probably be poor because his scarce working memory space will be cluttered with "noise" or useless information mixed with 'signal' or useful information. This effectively reduces the space available to deal with the "signal" further.

II - At the other extreme, a high working memory capacity, field-independent subject will perform well because he has ample space for thinking which is almost filled with 'signal' information with a relatively small amount of 'noise' compared to the field-dependent subject.

III - A high capacity, field-dependent subject, will perform less well than his field-independent high capacity opposite but will perform better than the field-dependent, low capacity subject.

Figure 1.2 shows the effectiveness of the same amount of irrelevant information 'noise' on the three different working memory capacities.

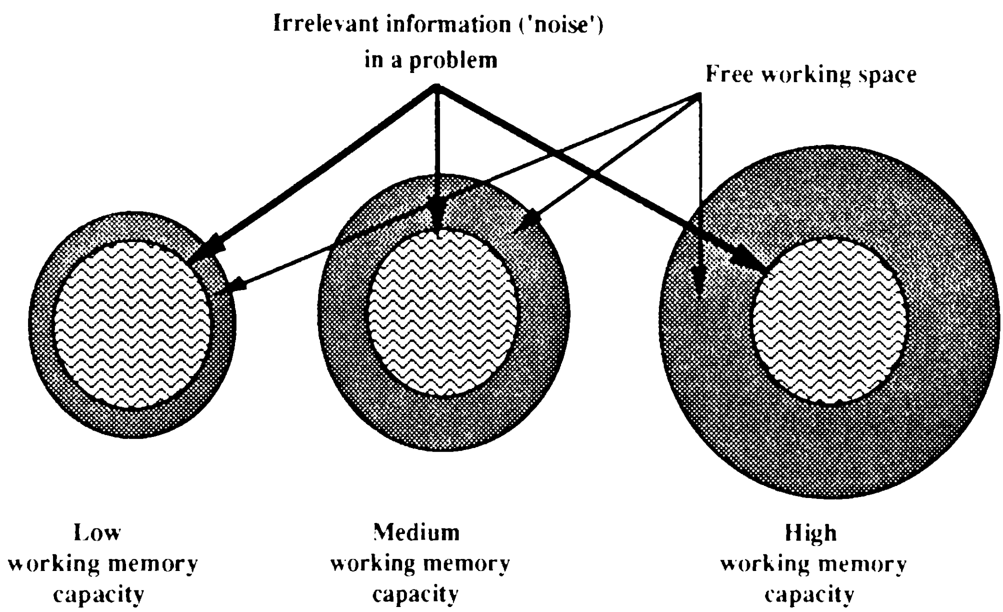

Figure 1.2 The influence of a same amount of 'noise' on the working memory capacities.

1.4 The Research Findings of the Previous Study

The outcome of the results in the researcher's previous study(1) reveal evidence that the field-dependent/field-independent cognitive style does influence the attainments of subjects in chemistry examinations. In each X-space category (table 1.1 and 1.2), it seems that field-independent subjects have the ability to obtain on average higher scores than field-dependent subjects in the same examination. At the same time, subjects who are field-dependent and of high X-space may perform better on average than field-dependent, low capacity subjects in the examinations. Also, subjects who are field-independent and of high X-space may perform better than field-independent low X-space subjects in such examinations. The largest positive changes in performance could be observed in moving from the attainments of field-dependent low X-space subjects to the attainments of field-independent high X-space subjects. (Table 1.1)

Interestingly, there is little variation in performance between high X-space, field-dependent subjects and low X-space, field-independent subjects. Such variation in performance was illustrated in Johnstone and Al-Naeme's (1991)[13] work using the terms of 'potential' capacity and 'usable' capacity. It could be that in a situation where no irrelevant information is presented a subject can perform to his full capacity, but in a real problem solving situation, where 'signal' and 'noise' both exist, the subject may suffer a drop in performance. In other words, a high X-space, field-dependent subject would carry a relatively large amount of 'noise' compared to the low X-space, field-independent subject. This amount of 'noise' may occupy some of the potential working space, leaving a reduced space for useful processing of the relevant information, the 'signal' of the problem. High X-space subjects in a case like this can not fully utilise their capacity and are performing as if their capacity were much reduced. The overall outcome of these results is supported by other recent studies[12,17]. Table 1.3 presents a table from one of these studies which exhibits these findings.

Table 1.1

The overall performance for subjects of different capacities and different degrees of FD/FI in a chemistry examination (Al-Naeme 1989)[1]

Capacity	Mean Scores %		
	F. D	F. Int	F. I
Low (N = 80)	53.2	58.3	59.3
Middle (N = 64)	56.5	58.5	63.8
High (N = 91)	57.0	64.7	65.8

Table 1.2

The overall performance for the subjects of different capacities and different degree of FD/FI in another chemistry examination (Al-Naeme 1989)[1]

Capacity	Mean Scores %		
	F. D	F. Int	F. I
Low (N = 77)	36.3	38.2	45.2
Middle (N = 62)	42.1	44.8	47.4
High (N = 90)	45.6	47.0	49.1

N = Number of subjects F.Int = Field-Intermediate

Table 1.3

The overall performance for subjects of different capacities and different degree of FD/FI in a physics examination (Ziane 1990)[17]

Capacity	Mean Scores %		
	F. D	F. Int	F. I
Low (N = 86)	41.6	41.6	43.1
Middle (N = 26)	38.3	48.7	–
High (N = 37)	45.0	49.6	65.8

1.5 Options for the Convergent /Divergent Dimensions of Thinking

Despite the fact that subjects who were field-dependent and of low working memory capacity had achieved rather lower performance results than others in conventional chemistry examinations, it was mentioned at the beginning of this chapter that some subjects who do not do well in written examinations can sometimes do very well in practical problem-solving tasks, and even better than some subjects who would be regarded as 'more able' on the base of conventional examinations. Therefore, some other factors must be operating in addition to capacity and field-dependence/field-independence.

Such observations were gleaned from teachers' opinions of the subjects in schools through interviews as well as from some records of subjects achievements in chemistry tasks.

Therefore, this study has to ask the question as to whether it could be that there are other psychological factors apart from the X-space and field-dependence/field-independence which may affect the subjects' thinking and learning procedures. Such suggestions demand further examination through the various disciplines of psychology, education and chemistry.

During research conducted in schools[1], it was found that some subjects tend to use long and convoluted methods to reach any chemical solution. Those subjects are more capable than others of offering a variety of answers to each question which may be asked concerning their everyday life. Nevertheless, some of the subjects are able to show a good, efficient solution to many problems in chemistry. By contrast, some other subjects tend to use short and concise methods to reach the answer. Their ability consists of a narrowing in focus, an imaginative austerity which is quite formidable. These subjects may exhibit less ability in giving a variety of answers to any question related to their life.

A search of the literature reveals that, Getzels and Jackson (1962), and Hudson (1966)[18, 19] have written of many studies regarding a field called *Convergent and Divergent Thinking*. The subjects of this study who are classified as more capable than others in elaborating the way to an answer and are skillful in giving a variety of answers to every day life questions may be called, accordingly, divergent thinkers. Whilst at the same time subjects who are using a single way to describe facts and are not so skilful in giving a variety of answers to every day life questions may be called convergent thinkers.

Convergent thinkers have been distinguished and defined by their comparatively high scores in problems requiring one conventionally accepted solution clearly obtainable from the material and the information available. They would obtain low scores in problems requiring the generation of several equally acceptable solutions. Using the reverse would define the divergent thinkers.

Divergent thinkers showed an ability to be more creative than convergent thinkers (as will be examined in this study). Creativity is an ability which most of us are concerned to develop and foster. It becomes a very important objective for educators to see creativity being encouraged in the classroom and the laboratory. Creative thinking occurs when the boundaries of the known are first mastered, through convergent processes, and then extended, by the application of divergent processes[20].

Therefore, this study has taken into consideration the fact that it is not only the working memory capacity and the field-dependent/field-independent factors which may affect people in their way of thinking or learning but also the means by which subjects reach the solutions.

One of the most important aims of the study is to ascertain whether the subjects who are classified as field-dependent or field-independent will think in a divergent or convergent way in solving the chemistry problems or vice versa.

1.6 Individual's Motivation in Learning Procedures

The factor of *Motivation* is another psychological factor recognised as important to this study. An attempt was made to ascertain if this could dominate the learning procedure in some way, and if it is related to the other previously studied psychological factors.

It would appear at present that there is only a limited amount in the literature for the work concerning motivation. The researcher intended to find some means of determining how an individual's motivation affects him/her in the process of learning. At the same time, the researcher will seek to determine any correlation between motivation, field-dependence/field-independence and convergence/divergence.

The early work which has been done in this field[21] attempted to divide the subjects into four categories: the *Achiever*; the *Conscientious*; the *Curious*; and the

Social category.

The Achiever subject[22] seems to have a distinct preference for an expository method of teaching and learning. He enjoys the challenge of competing with others for top marks and hates being held back by a teacher who has to deal with slow subjects. He seems to be apathetic towards any special interaction in learning.

The Conscientious subject also seems to display a distinct preference for an expository method of teaching and learning. But he also wants to know in advance the aims and goals of the work that he will be involved in with precise instructions which will allow him not to make mistakes. He will not participate in any unnecessary activities during exam times.

The Curious subject may be assumed to have a strong preference for discovery and problem-solving activities. He seems to prefer open-ended learning tasks, likes to follow his own practical ideas rather than rigid instructions.

Finally, the Social subject seems to be very sociable in all his activities. Even during his studies, he prefers to study with friends and to discuss problems together. He is often too involved with the external world to commit himself to consistent studying.

1.7 Practical Problem-Solving Projects as a Chemistry Element in the Present Study

As stated earlier in this chapter, attention was given to the performance of subjects in practical problem-solving in chemistry or what is called 'chemistry at the bench'. It was found that some subjects have a potential capability which seems to be hidden under normal classroom circumstances. Therefore, an aim of this study was to find a special activity in chemistry for all learners which would foster, that potential capability.

Accordingly, *Mini-Projects*[23] were chosen to provide such experiences and applied to pupils in the secondary level of education. These projects, as it was stated[24], were "carefully formulated and appropriate problems can generate a great deal of motivation and involvement for pupils of all abilities".

Mini-projects are small projects in chemistry concerning either everyday life technical problems or depending on previous knowledge. Most of them are open-ended and can possibly be used as creative tasks or as a means measuring the degree of creativity of pupils.

Mini-projects have been designed, on the other hand, to manufacture an interaction between trained and untrained minds[25] as an educative process. They are to train all types of minds of youngsters in chemistry.

Teaching, learning, manipulating, discussing, experimenting, and improving skills and understanding are all happening inside classrooms which are involved in the mini-projects procedure.

Once again, pupils who are classified as 'weak' in chemistry will be the concern of this study. Following them from early work in field-dependence/field-independence, convergence/divergence, and motivation to the mini-projects achievements is potentially extremely interesting.

However, other subjects will be observed similarity in order to trace a pattern in an attempt to summarise the factors involved in the learning procedure in chemistry, using the researcher's sample in secondary schools and with a firm dependence upon psychology.

Ultimately, it is essential to begin this work by focusing on the literature review of each psychological factor independently, to comprehend the effectiveness of these factors in the learning procedure of pupils in the secondary level of education. Additionally, some attention will be paid to the teaching strategies and the design of practical problem-solving in chemistry.

CHAPTER TWO

AN OVERVIEW OF VARIOUS PSYCHOLOGICAL FACTORS IN THEIR CONNECTION WITH SCIENCE EDUCATION RESEARCH

2.1 Introduction

No discipline exists alone or provides us with self contained units of thought which do not connect with other disciplines. There is a fine mesh of connections between psychology and science education. The researcher intends to utilise the discipline of psychology not as an end in itself, but as a means of map-reading, providing a route into science education itself.

In the following chapter the researcher's purpose is to consider issues of psychology alongside the theories of science education so that points of guidance become markers, which future research may erase, shift into new positions or delineate afresh.

The researcher, in his investigations into psychology, borrowed, selected, and discarded extensively from the literature. Such an overview allowed an array of choices to be made which led to the formation of three basic and manageable groups which will be described as *Field-Dependent/Field-Independent* cognitive styles, and the dimensions of *Creativity* and *Motivation* in the learning of science.

2.2 The Effectiveness of Field-Dependent and Field-Independent Cognitive Styles in Learning Procedures

In recent years, the idea of how field-dependence may be related to individual differences in learning and memory has been the popular subject of many studies, probably because it represents the confluence of two important streams of thought in the history of cognitive psychology.

One main subject of consideration has been the learning procedure and, implicit in that, how the individual processes, stores and retrieves the information. At the same time, consideration has been given to the issue of perception. Such concerns may be applied to the individual differences in learning and memory according to the field-independent cognitive style.

Cognitive styles can be defined[25] as "dimensions of individual differences involving the form of cognitive functioning, with expressions in a wide array of content areas including perceptual, intellectual, social-interpersonal and personality-defensive processes".

2.2.1 What are Field-Dependent/Field-Independent Cognitive Styles?

It is fair to mention that the work of Witkin and his colleagues (1954, 1969)[26, 27] generated a wide-spread interest and stimulated much research by others in the study of field-dependent/field-independent. Witkin defines[28] an individual who can readily 'break up' an organised perceptual field and separate easily an item from its context, as a field-independent individual, whereas the individual who has difficulties in separating an item from its context would be defined as a field-dependent individual.

Field-dependent/field-independent factors are most commonly measured by some variant of the Embedded Figures or Rod-and Frame Tests[28, 29, 30]. Field-independent people have the ability to overcome embedding contexts in perceptual functioning. This ability may give them a sense of separate identity, with internalised values and standards that allow them to operate with a degree of independence of the social field. In contrast, field-dependent people do not have the ability to overcome embedding contexts in perceptual functioning. Their expressions of articulated functioning in one area are related to expressions in other areas.

2.2.2 The Implications of Field-Dependent/Field-Independent Cognitive Styles for Learning and Memory Processes

Although there are few relevant investigations concerning the implication of field-dependent/field-independent cognitive styles for learning and memory, some studies sought to understand the relationship between cognitive styles and learning-memory abilities. Goodenough (1976)[31] made an attempt to combine the studies in his analysis of the relationship between the field-dependent/field-independent dimensions and the behaviour of individuals in the learning-memory domain. Four major areas of work are recognised and will be summarised as follows;

2.2.2.1 The Effect of Cue Salience in Concept Learning

The main principle in concept learning is that if the individual encounters concept-attainment problems, he will try to distinguish between the exemplars and the nonexemplars of a class of stimuli. He will then make an attempt to form hypotheses about the definition of the class of concept, such hypotheses being determined by using a variety of techniques.

It was found[32] that field-independent people may achieve better than field-dependent people in a typical concept-attainment problem, when stimuli are composed of a number of attributes. This kind of problem requires perceptual analysis of the stimulus complex into its attribute components.

Field-dependent people would show an ability to adopt hypotheses about the concept definition which favour certain cues and would neglect the nonsalient cues in constructing hypotheses. They are particularly dominated by salient cues in their hypothesis formation. On the contrary, field-independent people would sample more fully from the cues available.

2.2.2.2 The Approach to Learning Material

The mechanism of learning involved in any new concept is dominated by the need for continuity [31] during the process of concept attainment. Each attempt adds a new value to what is learned. Eventually, a gradual reduction in errors would occur until the criterion for success is achieved. It is important to state here that improvement in performance does not happen during the process of learning until the correct hypothesis is discovered which may lead to the learning attainment.

Accordingly, Nebelkopf and Dreyer (1973)[33] classified two curves in learning procedure in different subjects; the continuous and discontinuous learning curves.

They concluded that there are two kinds of learners; learners who have a spectator and discontinuous role and learners who have more of a participant and continuous role. The first category reflects people who are field-dependent in the learning process, while field-independent people tend to be having a participant and continuous role since they can show a greater structuring ability in the learning process.

2.2.2.3 The Use of Repression as a Defence Mechanism

In the present study, the term repression refers to the failure to recall information as such information would produce anxiety if that information were to become conscious. This study does not seek to discuss repression in its relevance to psychology but rather to discuss that aspect of repression which may affect the learning procedure.

Witkin (1974)[29] claimed that field-dependent people may use repression as a defence. Studies of repression show that the use of memory for stressful versus neutral material is more likely to be used by field-dependent people rather than field-independent people. In any act of perceiving, field-dependent people are more affected than others by stressful material. It is believed that this is due to the salient factors.

2.2.2.4 The Social Orientation

What concerns learning related to social orientation is that people who tend to be more socially orientated are supposed to be field-dependent people and may acquire more social information with greater ease than their field-independent counterparts.

Research in this area appears to agree that it would seem evident[31] that field-dependent people pay more attention to the significant social aspects of their environment. They tend to acquire significant social cues and ignore others, relying on their relevance to the task at hand. This acquisition may aid performance or sometimes hinder it. In contrast, field-independent people pay less attention to social cues unless their attention is specifically focused on such cues for some reason.

When field-dependent people encounter insufficient or ambiguous information, they tend to rely on the views of others more than field-independent people do. Field-independent people tend not to rely on others when they face ambiguous information and therefore may be described as more self-sufficient than those who are field-dependent.

2.2.3 Field-Dependent/Field-Independent Learners and Processing the Given Information

Research in this area shows[34,35] that field-dependent and field-independent learners differ in the cognitive processes that they employ as well as in the effectiveness of their performance. It is believed that field-dependent learners exhibit less efficient memory strategies than field-independent learners when they encounter a problem. The explanation of the poor memory of field-dependent learners is that they process information in a rigid way which may be the result of an inefficient response to cues which would facilitate their recollection of the past information. Frank and Davis (1982)[36] found that rigid information processing on the part of field-dependent learners may cause confusion in any attempt to ascertain alternative meanings of clues or shifts in clue strategies, thus hampering performance.

Field-dependent learners may encounter difficulties in recalling encoded information unless retrieval cues are directly relevant to the way in which the information was encoded. For field-independent learners, this may not be the case - they may recall encoded information without depending directly upon relevant cues. The relevant cues could be considered as 'bridges'[35] to aid access to the stored information.

Furthermore, studies related to cognitive restructuring skills emphasised[15, 37] that field-independent learners are more capable of cognitive restructuring skills than field-dependent learners. The procedure of cognitive restructuring comprises of firstly, the ability to break up the task into its basic elements, secondly, the ability to manufacture a structure from an ambiguous stimulus complex which will be the outcome of such procedures, and thirdly, the ability to make a different organisation of the task than its initial structure in the stimulus complex.

Studies in memory regarding field-dependence/field-independence have shown two important areas[38] that must be briefly discussed. These are short-term memory and free recall.

2.2.3.1 Short-Term Memory

In an attempt to compare between field-dependence/field-independence and short-term memory, Berger (1977)[39] used the digit span test and two measures of field-independence to find out whether there is any correlation between these variables. The results imply that field-independent learners are more capable than field-dependent learners in resisting the interference which would happen in short-term memory tasks. In general, field-independent learners showed a high performance in memory tests involving interference than others. Thus, the ability of this group of learners to focus attention on relevant aspects of a situation is high, as compared to field-dependent

2.2.4 Field-Dependent/Field-Independent Cognitive Styles and the Central Computing Space ('M-Space')

Pascual-Leone (1970)[6] stated that all cognitive processing occurs in a central computing space which is labelled as the 'M-space'. Pascual-Leone's work is based upon the Piaget theory of the intellectual functioning. It would appear that Pascual-Leone's work has wide-spread relevance and thus has encouraged much research[42, 43, 44]. Pascual-Leone's work, in conjunction with a burgeoning of research, has resulted in the Neo-Piagetain theory. Pascual-Leone believes that field-independent ability is a developmental characteristic and learners with this ability may have at the same time a high M-space in which case they may be described as high M-processors. Building on this, the researcher's previous work[1, 13] follows many of Pascual-Leone's basic assumptions.

A decrease in field-dependence with an increase of age (up to the age of 16) occurs[6, 43] due to the developmental changes in the M-space of any individual as well as some other development changes in the conceptual knowledge or processes coordinated in the M-space.

Stated in the previous chapter, the M-space has been given many different names such as X-space[1] or working memory[4]. However, it was found[42] that the performance of field-dependent learners revealed a poorer level of performance than field-independent learners when the burden of tasks was increased on the working memory.

Also, the Neo-Piagetain theory has drawn[44] conclusions about a disembedding situation showing that any learner would need a relatively large amount of central computing space for use in the process of generating a conceptual response. Accordingly, field-dependent learners would exhibit a poor performance in such a situation since they do not use or have available for use sufficient central computing space.

2.2.5 Field-Dependent Individuals in a Problem-Solving Situation

While it has been emphasised in many parts of the present chapter that field-dependent learners have a less efficient memory than field-independent learners and therefore field-dependent learners may display a low performance in many tasks because of their small 'M-space', there is as yet one pertinent aspect which has not yet been discussed concerning the ability of these two categories of learners in a problem solving situation.

In a problem-solving situation, the learner may encounter a problem which is not familiar to him, especially, if this problem is an open-ended one. Learners could face such a situation in a school laboratory, in the classroom, or even in the outside world manifesting itself as an every day problem.

In literature, a considerable amount of research has been subjected to the comparison between field-dependent and field-independent learners on various occasions. In spite of this, there has almost been no analysis of the nature of these learners facing problem-solving situations.

However, it was found(37) that field-independent learners would be more likely (than field-dependent learners) to exhibit a good performance in problem solving situations when the solution depends on using an object in an unfamiliar way. When previously useful cues become irrelevant in the current concept formation task, the performance of field-dependent learners suffers more than field-independent learners(45, 46).

Therefore, it is possible to look at this assumption as an access to the next section of this chapter in which the researcher will discuss other psychological factors such as *Convergence* and *Divergence*.

2.3 Convergent, Divergent Intellectual Styles and the Enhancement of Creativity in Science Education

In the 1960's, educators were alerted to the attitudes of learners towards subjects chosen during the secondary level of education. It became apparent that some learners preferred to do science subjects, whilst others were motivated to do arts subjects.

Based upon Getzels and Jackson's (1962)[18] work, Hudson (1966, 1970)[19, 47] found that learners who excelled in science tended to have an interest in technical hobbies and outdoor activities, whilst learners who were better in art subjects had cultural interests like music, drama, and poetry.

Getzels and Jackson (1962)[18] formulated a distinction between the two categories of learners; the first category was called the 'High IQ' learners who are good at intelligence test in terms of scores, but relatively weak on tests of 'creativity'. The second category was called the 'High Creative' learners who are good at the 'creativity' tests but scored relatively low in intelligence tests.

In a comparative study between scientists and arts-orientated learners in the I.Q. Test, Hudson (1966)[19] observed that scientists performed better than their arts-orientated colleagues in the I.Q. Test. His conclusions were that the science subjects generated problems which tended overwhelmingly towards one correct solution; whilst the arts subjects frequently encouraged learners to discuss and manipulate ideas, with a view to developing original responses. Furthermore, the science subjects had a bias towards numerical and diagrammatic questions. On the other hand, the arts subjects are almost completely verbally biased.

2.3.1 Convergent and Divergent Styles of Thinking

"Convergent thinkers have been defined and distinguished by their comparatively high scores in problems requiring one conventionally accepted solution clearly obtainable from the information available (as in intelligence tests), whilst at the same time obtaining low scores in problems requiring the generation of several equally acceptable solutions (typified in divergent thinking test). The reverse arrangement defines divergent thinkers"[48].

The convergent/divergent thinking style refers to the tendency of some learners to depend upon a mode of thinking which leads to logical conclusions and uniquely correct or conventionally accepted solutions, while other learners tend to depend upon thinking which leads to a variety and quantity of output.

In the classroom, the application of this may be found[47] in training learners. Teachers habitually teach science students to focus their thinking onto the answer; they must converge their thought-processes towards the one correct solution. In contrast, teachers would encourage arts students to use versatile thinking, to search for a variety of responses: they must therefore diverge their thought-processes.

In brief, several ideas or facts would be recalled, manipulated and formulated to reach an answer in terms of convergent thinking. These ideas are ordered in such a way as to converge towards the one correct answer.

While, in terms of divergent thinking, ideas or facts would be speculated upon, brainstormed, and fashioned into new inventive possibilities. Such thinking is characterised by not having enough information to produce only one acceptable answer. These ideas would branch out into a multitude of reasonable answers[49].

2.3.2 Hudson's Divisions of Learners into Convergent and Divergent

Hudson (1966)[19] divided his school sample of boys (on the basis of open-ended tests and IQ tests) into the divergers (30%), who are substantially better at the open-ended tests, and the convergers (30%), who are substantially better at the IQ tests, whilst there were also what can be termed the all-rounders (40%), who are more or less equally good (or bad) at both kinds of test.

The sample was then subdivided into; extreme convergers (10%); moderate convergers (20%); all-rounders (40%); moderate divergers (20%); and extreme divergers (10%). However, Hudson neglected the all-rounders group from the study to obtain two contrasting groups which would facilitate his study.

Hudson has emphasised that the convergence/divergence dimension is a measure of bias, not of level of ability, since it is possible for a converger to obtain a higher open-ended score than a diverger by having a quite exceptionally high IQ score, or because of the diverger's IQ may be exceptionally low.

The results showed that most arts specialists displayed a poor performance during IQ tests but were much better at open-ended tests; whilst scientists proved to be the reverse. It would appear that arts specialists were on the whole divergers, while physical scientists were convergers.

The teacher may play a most important role in shaping the style of thinking adopted. When children go to school for the first time; their beliefs, languages and attitudes have been primarily learned from the adults around them. In teaching subjects, teachers express the manner of thinking which they think is most useful, although not necessarily most appropriate for success in that particular subject. Therefore, to take chemistry as an example, the learner will be taught not only the facts of the subject, but also a convergent way of thinking which, to a great extent, will be imposed upon on him.

The teacher may encourage learners to recognise that there can be only one correct answer to many chemistry problems although this argument may prove sterile in some cases when it is possible to employ more than one solution. The convergent may, encounter difficulties when he tries to utilise unconventional methods.

Hudson suggests[19] that learners have already chosen a manner of thinking to employ whilst at school and, if left to themselves, they will choose a subject in which they are particularly strong, perhaps one in which they find a congenial thinking mode.

2.3.3 Various Taxonomies of Thinking

Educators are concerned with the fact that there are many levels of thinking which learners might use in executing any task. Learners must not only recall the material, but also understand it and be able to work with it.

Pavelich (1982)[49] has exhibited three taxonomies shown in table 2.1 which may be needed when the student encounters questions which require different kinds of thinking.

Table 2.1

Pavelich presentation of Taxonomies

Blosser	Bloom	Piaget
1. Cognitive memory (recall)	1. Knowledge	Concrete
2. Convergent Thinking	2. Comprehension	Formal or Concrete
	3. Application	
	4. Analysis	
	5. Synthesis	
	6. Evaluation	
3. Divergent Thinking		Formal or Concrete
4. Evaluative Thinking	6. Evaluation?	Formal or Concrete

In the table above, there are three kinds of taxonomies presented by Blosser (1973, 1975)[50, 51], Bloom (1956)[52] and Piaget (by Ginsberg and Opper. 1969)[53].

In the first column, Blosser has given four types of thinking, the first type relates to what is called 'cognitive-memory' using thoughts which may be recalled and used at a given time. The second type is of particular relevance to the present study as is the third type of thinking, it involves the convergence of ideas to achieve the correct answer (convergent thinking), or the branching out of ideas towards a large number of reasonable answers (divergent thinking). The fourth type of thinking is similar to the third one; it needs several answers too but in evaluative thinking one must choose from a range of possibilities as well as justifying one's choices.

In the second column, Pavelich has reported[49] similarities between Blosser's and Bloom's taxonomies[52]. But Bloom's taxonomy emphasises almost exclusively, aspects of convergent thinking. Therefore, Bloom has not defined well the divergent and evaluative types of thinking, by giving only what he labelled evaluative thinking. Blosser's taxonomy, on the other hand, emphasises the important aspects of divergent and evaluative types of thinking which he refers to as the open-ended thinking.

In the last column, Piaget presented[53] two kinds of ideas concerning the age of college students. These consist of a concrete content which includes what is observable as qualitative, or involves one-to-one correspondence, and a formal content which includes functional relationships or combinatorial correspondence (Intellectual Stages of Development). Pavelich has stated[49] that Piaget's theory clarified the issue when he stated[54] that many college students may not be able to reason with formal content since they have not yet developed mentally to an extent which will allow them to understand the formal content. Thus, many college students would reason only with concrete or early formal content.

To conclude, Pavelich described the combination of Piaget's and Blosser's taxonomies as the best means of advancing the teaching of chemistry. He stated "In terms of these two, the goals of a course are to use the study of chemistry to (1) enhance the convergent, divergent, and evaluative thinking of the students, and (2) to deepen their abilities to reason with formal content. In practice these are complementary goals".

2.3.4 The Effectiveness of Creativity in Science Education

One of the most important findings in research which has been conducted in the discipline of thinking is the existence of a significant relationship between the divergent test scores with the creative variables and interests[55].

2.3.4.1 What is Creativity?

There is a considerable emphasis in instructional theories indicating that learners must find their own ways of formulating hypotheses and generalisations which would allow them to finish each unit of study with a genuine feeling of having created and discovered ideas for their own benefit.

Teachers must foster the ability to discover and inquire in learners of science. Such ability should develop and enhance a habit of creative activity which eventually emerges as another human skill. Sadly, this has rarely been an expectation common to the classroom - there seems to be little emphasis on creative teaching.

'Creativity' may be defined as "the ability to combine ideas, things, techniques, or approaches in a new way"[56]. Therefore, in learning for instance, if the learner has invented a technique which he has not been trained to use or read about, even though others may have previously used it or even found it in literature, a technique like this would be considered 'creativity'.

Relying on Talyor's (1963)[57] work on the process of creativity, Romey (1970)[56] has reported four stages of the creative process. Such stages would be involved in any problem:

"1. A period of mental labor and deep involvement in a problem: This may involve a seemingly fruitless struggle with some aspects of an out-of-the-way part of the problem.

2. An incubation period: The idea is dropped for a while to see if anything will hatch.

3. A period of illumination: The 'Ah-ha!' period.
4. A period of elaboration and refinement of an idea."

2.3.4.2 Why is Creativity Important?

Almost all the literature points out that creativity has solicited a great deal of concern within science curricula and in learning and teaching strategies. It has been emphasised[58] that the creativity process is not a static aspect of any individual but is an intellectual characteristic that could be stimulated, nurtured and trained.

Therefore, creativity may be considered to be important since:

* in science, it is considered to be a fundamental process and may at present be treated as a prime feature in designing science curricula.
* in problem-solving matters, creativity represents the most important element that may be employed by learners. It is in the central core of problem-solving objectives.
* at times it is required in some practices in science.
* it must be inculcated in all its forms continuously, otherwise it will not develop.

2.3.4.3 How to Measure the Creativity

Various tests have been set up to measure the development of creative thinking in learners. As stated earlier in this chapter, Getzels and Jackson (1962)[18], Hudson (1966)[19] and many others have used what are called 'open-ended tests' to measure the 'creativity' of learners (divergent thinking ability).

Although the idea of what constitutes an 'open-ended test' does not differ greatly from one research project to the next, concern[60] surrounds these tests and there is some difference in opinion concerning the criteria they use and their validity. However, Guilford and Merrified (1960)[61] used the following tests to measure the creativity of learners:

I - The Apparatus Test: to determine what may be improved in the general use of apparatus (e.g. chemistry discipline).

II - Seeing Problems: learners proposals of problems in connection with common objects.

III - Match Problems: making different patterns of matches that can be removed to leave a specific number of squares.

IV - Topics If: writing as many as possible ideas about a given topic.

V - Brick Uses: inventing various uses for a brick.

VI - Alternative Uses: writing different unfamiliar uses for common objects.

VII - Gestalt Transformation: learners must list which of five mentioned objects has a part that will serve a particular purpose.

VIII - Object Synthesis: learners must name an object that could be made from a combination of two specific objects.

Generally, the scoring of these tests would depend upon the number of acceptable responses which the individual gives.

2.3.4.4 Some Ways in which 'Creativity' can be Used

During the literature discussion of this chapter, it was stated that learners may create some unfamiliar usage of ideas in a way which leads to a new working combination. However, Lucas (1971)[62] summarised some ways in which creativity can be used:

I - To make any change whatsoever.

II - To generate new ideas from the usual pattern of thought.

III - To produce new ideas or concepts about the discipline or the individual's society.

IV - To produce a new formulation or meaningful pattern (for the individual).

V - To enrich the procedure of scientific investigation.

2.3.4.5 The Vital Components of Creativity

Creativity as a style of thinking is made up of two major components. These are usefulness (or utility) and originality[59]. Both of these properties must be found in anything one considers to be creative.

Originality, on the other hand, could be defined as:

"**I** - New concepts.

II - New combination of concepts.

III - Standard application of new concepts.

IV - New application of old concepts.

V - Standard application of old concept."

Creativity also needs the immediate applicability and usefulness of ideas, otherwise these ideas will be rejected by learners. Therefore, the intellectual risk-taking which is involved in true problem-solving may not be exercised.

Garrett (1989)[59] has combined utility and originality by drawing a diagram between them as shown in Figure 2.1. A positive correlation between the axes (originality versus utility) indicates the existence of creativity in a task. The degree of creativity would be obtainable from the degree of positive correlation between originality and utility.

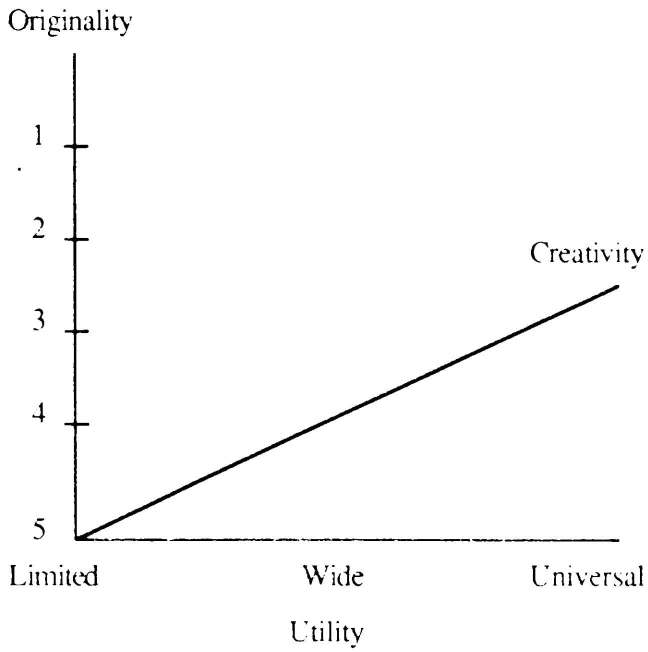

Figure 2.1 Garrett relationship between originality, utility and creativity.

2.3.4.6 Creative Thinking and Problem-Solving

A move towards enhancing creative thinking in problem-solving situations occurred[63] in the 1960's. The change of methods in science teaching moved towards some emphases on creativity and therefore stimulated a need for open-ended laboratory activities proving them as essential, during which learners would be involved in a problem-solving situation. It is believed that a problem-solving situation could provide the best opportunity for learners to develop their creative thinking.

To enhance creative thinking in the laboratory, a problem would be given to the learner for which he or she has not yet learned a method of reaching a solution, or the problem itself should not have yet been identified by the learner. It is assumed that problem situations like this would encourage the development of skills which are considered to be creative and original. Encouragement for this kind of laboratory activity may be found in several studies[59, 60, 64-68]. Further details about open-ended tasks and a problem-solving approach will be elaborated later in chapter three.

2.3.5 The Interaction between Students' and Teachers' Convergent/Divergent Thinking Styles and Personalities

Students are thought to have criteria by which their teachers could be ranked as convergent or divergent thinkers. However, these criteria may coincide with the teachers' estimates of themselves and of each other. One the other hand, teachers' identification of particular students as convergent or divergent thinkers would coincide too with the students' estimates of themselves and of each other. These ideas are found in Joyce and Hudson's (1968) study[69], and suggest that teachers and students probably do recognise personal qualities easily and consistently in themselves and in each other.

A further concern may be expected concerning the effectiveness of the teaching of convergent students by convergent teachers, and the teaching of divergent students by divergent teachers. It was found that students who had low convergence scores or high divergence scores tended to do poorly in examinations, if they were taught by convergent teachers. These students were found to perform significantly better in some examinations than in others if they were taught by divergent teachers.

Joyce and Hudson (1968)[69] stated that "It does not always seem to be true that like learns best from like : that convergent students learn best from convergent teachers, and similarly, for the divergers".

It seems beyond prediction[70] what effect a teacher's thinking style will have upon his students until his interaction with them has been studied once at least. The nature of the interaction should be consistent from one year to next and in some circumstances may be stable over a longer time.

2.3.6 What Sort of Thinking is Important to Enhance in the Classroom?

The answer to this question will simply be that every kind of thinking style should be encouraged by placing the student in a situation where he/she can and must do such thinking. Convergent, divergent and evaluative thinking could be enhanced[(71)] if firstly, the teacher's questions are properly structured, that is to enable students to give divergent and evaluative responses. Secondly, the students should be properly stimulated by the kind of questions teachers asked to allow students to give convergent responses. In general, students learn to respond in ways that are directly related to the kind of questions which teachers ask and to the things they are rewarded for.

Additionally, creative thinking would remain the most important outcome of thinking styles. It should flourish in the classroom as in the laboratory, since it represents the very essence of science. Teachers may play a crucial role in enhancing creativity in classrooms. Penick (1990)[(69)] has given several pieces of advice to teachers in how creativity could be healthily grown in classrooms:

I - Teachers must provide time, materials for and an expectation of creative work. They must carefully and consistently structure the classroom to maximise opportunities for creative thinking.

II - Teachers must ask questions which seek opinions and points of view. If the teacher wishes to stimulate students' involvement and creativity, he must never ask a question that he already knows a definitive answer to, for which he requires no more than a Yes/No answer, and which requires little more than recall..

III - Teachers must wait for responses after having given a question. They must not pressurize students to rush into making hasty judgements. Rather, students must be given time for observation, contemplation, response and reflection. Moreover, teachers must wait for and encourage multiple responses.

IV - When teachers obtain unusual ideas, questions, or products from students, they must accept that as a concomitant part of creativity. However, teachers must not give judgement in these cases but only acknowledge any answer or idea and hopefully ask for some development of any idea or response.

V - Teachers must ask students to examine any assumed case as well as its consequences. For example, if what you have said is true, why..? What may have caused that and what will be its result?

VI - Teachers must allow students an opportunity to structure their activities and make decisions concerning those activities.

VII - Teachers can build a model for creative thinking in the classroom by asking questions themselves, expressing curiosity and allowing room for stimulation.

In brief, the procedure of creative teaching in the classroom can operate at three levels[(56)]:

"**I** - The teacher must be combining ideas so that they are in tune with mental processes going on among the students.

II - The student must be responding to the teacher's stimuli by combining and recombining their own and the teacher's ideas in various ways, searching for meaningful conceptual relationships.

III - The teacher must be receiving the student's ideas, evaluating them, recombining them in yet other new ways, accepting them, shaping them, and throwing them back to the students for further elaboration."

2.3.7 Creativity and the Shape of Science Education

If educators seek to promote creativity in science education, they ought to modify the shape of science education in order to encourage students toward creativity. Therefore, a number of suggestions may allow this[73]:

I - Science education must move from mere memorisation in the realisation that memorisation must be accompanied by understanding through problem-solving, like open-ended problems or scientific problems which have more than one unique correct answer. Although the type of problem that is found so often in textbooks requires one unique answer which is not always characteristic of the way science actually works in practice. There are also many problems which may arise in the course of searching for new knowledge which is open-ended and not amenable to a closed answer. Therefore, open book examination is an ideal means of approaching creative problem solving which is at the same time a means of reducing rote learning and sterile memorisation.

II - Experimental methods should be encouraged in science teaching. This suggestion would be valid if educators believe that knowledge is not closed and therefore new ways of acquiring knowledge may be demonstrated to the students.

III - A suggestion may be made concerning the content of science education, the syllabi, the thesis topics, or the list of 'prescribed' courses. All these elements could be considered to be of secondary importance when compared to the training in research methods and the development of attitudes to science. The science curriculum should therefore become more flexible, without losing its need to have a core of required content.[64]. This type of curriculum would be beneficial in giving students a higher degree of autonomy within the curriculum. The shift into a more flexible programme would develop better scientific methods in students than a syllabus-bound programe which dictates limits for studying science.

IV - Another suggestion concerns personal traits such as motivation. It is believed that being creative means being unconventional, nonconformist, living one step ahead of one's time. As children grow up and may move towards creating something novel may often mean unfortunately that one encounters indifference, incredulity and sometimes even hostility from society and from colleagues within the scientific community. Accordingly, creative people must have very strong internal motivations enabling them to be involved in scientific activities which any system of local education should not deter, but rather assist and reinforce such inner motivations in students. However, the concept of motivation will be discussed in greater length later in this chapter.

V - Regarding the practice of creative science it can involve learners of any age and it is essential to involve perseverance, skill and consistency in carrying out a project from the point of conception to the final implementation of it.

In conclusion, science itself must be viewed afresh as a novel and creative human activity in order to allow creativity to be more effectively converted into achievements and accomplishments. This view would allow some first steps towards the restructing of science education and would allow us to do justice to science education as a field which enhances and fosters creativity.

2.4 A Review of Students' Motivational Traits and Preferences in Science Education

Attempts have been made in the past to match science curricular structure with the learner's developmental readiness, intellectual ability and cognitive styles. But not many attempts were found involving the motivational characteristics of learners in the learning of science. Ausubel et al. (1978)[5] reported "this estimate of relative importance is only an expression of difference in degree. Motivational (and other) characteristics are sufficiently important in school learning to engage our most serious consideration if we wish to maximise .... classroom learning".

However, some research in literature found[74, 75] that students' motivation could be enhanced towards learning in the context of school science education. Thus, some issues concerning motivation will be briefly discussed in the remainder of this chapter.

2.4.1 Areas for Motivation in the Subject Matter and Pedagogy of Science

Educators seemed to focus on two areas related to motivation; the subject matter and the pedagogy. They believed that students' motivation[74] could be enhanced by studying and promoting such areas.

2.4.1.1 The Subject Matter and Motivation

In this area, some suggestions were made concerning the nature, structure and presentation of the subject matter. It was found[75] that the subject matter seem to be 'remote' from learners. Therefore, a suggestion was made arguing that subject matter should be presented in different ways which would enable learners to see it as more beneficial and relevant. Eventually, this would create a significant relation between the leaner and the subject matter in which he/she would feel anxious to attend science lessons.

Several other suggestions[76-78] were made seeking a connection between science education projects and real life problems (applications and uses) to establish the relevance and the nature of science.

2.4.1.2 The Pedagogy and Motivation

As a general principle, science teachers try to stimulate and motivate learners towards science subjects. If this is true, teachers must use stimulating and motivating teaching strategies, otherwise, they may not manage to achieve such objectives. Teachers must direct[74] their pedagogical interventions and activities at learners to gain a direct bearing on learners' motivation.

It is worth mentioning that although the orientation, nature and structuring of the subject matter will primarily affect learners' interest towards any science course, the instructional procedures and learning environments which could be established by the pedagogy, would be more effective on learners' motivation in the teaching of science[79].

2.4.2 The Instructional Procedure Concept

Orbach (1979)[80] found that students of varying motivational orientations would respond differently to diverse instructional procedures. To approach an understanding of what the different instructional procedures are, one must inevitably discuss the interactions between teachers and learners which depend upon both the nature of their discussions and the activities in which they are involved[81].

Building on this, several dimensions of different instructional procedures could be distinguished[82]:

I - The mode of knowledge acquisition which involves the discovery learning procedure or expository teaching.

II - The nature of learning experience which involves the theoretical or experimental learning experience.

III - The control of learning activities which may be determined by the teacher or by the learner himself.

IV - The control of learning outcomes which may again be determined by either the teacher or the learner.

V - The working arrangements[83] which involve working individually or working in a group to exchange learning, knowledge and skills.

VI - The evaluation of learners' achievement, which would involve regular assessment by teachers or involve a preference for instructional situations in which learners can express their dislike towards being tested or assessed.

2.4.3 Students' Different Motivational Patterns and Preferences

As stated earlier, motivational qualities of any instructional procedure were found to effect substantially the function of such a procedure.

However, students' different motivational patterns, interests and preferences were also found to play a very important role in the procedures of learning and of teaching[21]. If there is an interaction between teaching techniques and the students' motivational patterns, a greater degree of learning may be accepted as occurring.

It is believed[84] that when students are confronted with new learning experiences, they meet them with different interests, values and motivations. Students differ according to their preferences for and responsiveness to different instructional features. Regardless of the actual context of learning, it is found[21] that the motivational patterns and preferences stay relatively stable in individual students. In other words, these different motivational patterns and preferences can be aggregated into clusters and therefore a study of them would be possible.

Adar (1969)[21] proposed four major types of need or desire as providing a basis for motivation to learn. They are; need to achieve, need to satisfy one's curiosity, need to discharge a duty, and need to affiliate with other people.

2.4.3.1 <u>The Achiever Student</u>

In an attempt to study this motivational pattern of students and other patterns, the researcher suggests a review of what was predicted, what was suggested in literature concerning these issues and to highlight the main analyses. Thus, the character of achiever students could be presented and summarised in the following ways:

I - Achiever students' preferences for discovery and for pursuing their own enquiry seem to be very high[83] and it could increase with the growth of students' achievement in such tasks.

II - Although, achiever students have a definite preference[85] for competitive learning environments, they tend to avoid activities which may involve more than a moderate risk[86]. It was suggested that these students select easy or intermediate tasks to begin with, but choose tasks of progressively higher difficulty whenever they experience success[87, 88]. It is worth mentioning here that tendencies to operate in competitive situations could lead to enhanced[86] learning outcomes.

III - It is believed that there is a subtype[89] of achiever student who tends to avoid failure with greater assiduity than they seek success. This subtype of achiever does not like to be involved in competition with others for the best performance in case of any failure. Thus, they feel uncomfortable in facing achievement-oriented situations.

2.4.3.2 The Conscientious Student

This type of student has been subjected to several studies. Some predictions and suggestions of this motivational pattern are summarised in the following:

I - One of the most distinctive characteristics of conscientious students is that they are more teacher-dependent[83] than students in other motivational patterns. Therefore, they prefer a teacher controlled approach to learning which well structured, well ordered learning tasks. They can show a clear preference for formal modes of teaching, with precise instructions to be followed. Moreover, conscientious students would like every achievement and progress to be supervised by their teachers.

II - Conscientious students seem to accept the idea of discovery learning provided that this kind of learning is linked to clear instructions and objectives[80, 90]. Furthermore, they can show a preference toward tasks which require a considerable amount of effort, such as learning by heart, summarising information and solving routine problems or extracting information from given texts[86].

III - Conscientious students regard the need to study and learn as duties[86] therefore failure for them would cause feelings of fear and guilt. They do not require any sort of external stimulation to fulfill their obligations.

IV - A further apparent preference of these students is for group learning activities[83]. Conscientious students seem to accept this as a means of gaining feedback and advantage for their own progress.

2.4.3.3 The Curious Student

Curiosity is considered as a cognitive scientific attitude[91]. However, it is another students motivational pattern which is summarised as follows:

I - One of the most distinctive preferences of curious students is their liking for discovery learning strategies[83]. Practical work or problem-solving activities are seen as favourable to this pattern provided they are not associated with precise instructions. Thus, curious students may be seen at times as in opposition to non-experimental work and prefer open-ended tasks.

II - These students dislike formal teaching in which no practical activity, novelty, or discovery through one's own enquiry may be found. However, if the classroom situation presented complexity and novelty they would be motivated[86] as that induces them to engage in exploratory learning.

III - A further characteristic of these students could be drawn from their general propensity towards open-ended learning. Curious students appear willing to engage in a higher degree of risk-taking in their learning compared to others because they seem to have a high failure tolerance[88].

To summarise this pattern amongst curious students, Kempa and Martin Diaz (1990)[83] stated "these observations, taken together, point to curious students having a preference for being actively involved in learning activities that require them to discover, to seek information and to make decisions. They evidently do not like to be simple 'receptors' of information which places them in the role of passive learners".

2.4.3.4 The Social Students

The most important motivational features of social students is their tendency towards seeking affiliation. The following is a summarise of of their characteristics:

I - The general motivational characteristic of social students is their need to affiliate[74] with others and therefore their preference for involvement in group work. They dislike being involved in individualised tasks[84, 90]. In general, social students' motivation increases when personal relationships are incorporated into the learning/teaching process.

II - Social students often fear rejection in personal relationships[80] and therefore they tend to avoid relationships which would bring about uncomfortable feelings.

III - These students prefer learning in non-competitive environments[83]. Regular testing signals such a competitive environment to the social student which is not conducive to their progress.

IV - Social students are very self-confident as to their success in the world of personal relationships. Also, they like to be involved in group work. Thus, the procedure of discovery learning suits them since it can be organised in the form of group work.

V - It was suggested that social students prefer a friendly and informal atmosphere in classrooms[86]. They would like to have opportunities to show their initiative and pursue their own enquiry. Dividing students' motivational patterns and preferences into four categories *does not* mean that:

* there are definitely four motivational patterns only, nor it does mean that all work in this area fitted students into the same categories as the present study. However, several studies used more or less than four motivational categories as well as a different nomenclature, depending on the objective of any particular study. For example, students' motivational patterns have been divided into the categories of success, social, dependent, alienated and phantom students in Good and Power (1976)[90].

* a student will have only one type of motivation. The motivation of some students results from the co-existence of different kinds of need; therefore, a curious student can be social as well, and a social student can be an achiever, and so on[86]. In other words, some students exhibit

mixed motivational patterns in which elements of one pattern can mix or develop with those of another. However, Kempa and Martin Diaz (1990)[83] found a high proportion of the total students' sample could be fairly clearly assigned to one of the four motivational patterns.

2.4.4 The Relationship between Different Instructional Procedures and Students' Motivational Characteristics

Previous research in science education placed emphasis on the importance of the power of different instructional procedures. Recently, attention has shifted onto[92] the interaction between the motivating quality of instructional procedures and students' motivational patterns.

In the light of this notion, it will be convenient to study the most significant instructional procedures which associate science teaching and learning with students' motivational patterns. These are discovery learning and problem-solving activities, open-ended learning activity, formal teaching with an emphasis on information and skill transfer and collaborative learning activity[74].

2.4.4.1 Discovery Learning and Problem-Solving Activities

The difference that should be reported between discovery learning and open-ended learning is that the latter needs an enquiry-oriented instructional strategy (discovery learning strategy) to be employed; whilst discovery learning does not require the open-ended strategy as it can work even when learning objectives and goals are fixed in advance.

Based upon Adar's (1969) work[21], discovery learning and problem-solving activities are practical orientations which are both designed for involvement both in laboratory work or in some circumstances field-work[93]. Thus, such tasks require or invite high 'risk-taking' on the part of the learner. Accordingly, these tasks and activities would best suit the curious student type of motivational patterns since these students are more likely to accept engagement in judgement and evaluation situations (high risk-taking) than students from other patterns.

It is reasonable to mention that in some laboratory work, students would neither confront genuine discovery tasks and problem-solving nor would they require high 'risk-taking'. Therefore, achiever and conscientious students would find such laboratory work to be more appropriate for their trends.

2.4.4.2 Open-Ended Learning Activity

Because this kind of learning activity will be discussed in detail in the next chapter, it is worth considering the interacting aspect of open-ended learning with students' motivational patterns. In brief, open-ended activity seems to have no specific objectives as a part of those associating with project work or student research(21). It is another kind of learning which requires students to engage in and practice high 'risk-taking', judgement and evaluation situations, or even higher engagement's level may be needed. Therefore, this activity is strongly preferred by curious students. At some levels, open-ended learning activity would negate the role of the teacher who directs students toward goals. Thus, it would not be surprising to see curious students only from other motivational patterns who prefer this learning activity.

2.4.4.3 Routine Teaching with Emphasis on Information and Skill Transfer

Routine teaching is the habitual form of teaching that takes place particularly in the classroom, of which teachers are the main instrument. It could be described as the conventional or traditional instructional procedure. It was found(74) that achiever and conscientious students prefer this type of learning activity which requires low level risk-taking.

2.4.4.4 Collaborative Learning Activity

Such a form of learning is best accomplished in a special atmosphere such as the laboratory or interactive exercise. Practical work in laboratories can enhance social relationships between students. Laboratory work could be organised in such a way as to allow every individual to contribute to any successful procedure. This may also require appropriate social skills for work with their colleagues. Thus, it is called a collaborative learning activity. Games and simulation exercises are examples of such learning activities.

Social students are recognised to have a positive tendency towards[21, 75] such kinds of learning activity, particularly strong social motivational students who describe collaborative learning activities as attractive. On the contrary, achiever students are likely to be opposed to such kinds of learning activity.

Table 2.2 shows the relationship between different instructional procedures and students' motivational patterns, quoted from Hofstein and Kempa (1985)[74].

Table 2.2

Relating instructional features to students' motivational characteristics, quoted from Hofstein and Kempa (1985)[74]

Type of activity	Exemplars	Comment (suitability/unsuitability)
Discovery/enquiry-oriented learning methods Problem-solving	Advocated in many science programmes developed in the U.S. and U.K. during the 1960s and 1970s. For example, Nuffield O-level and A-level science courses.	Suitable mainly for students with 'curiosity'-type motivational pattern. Insofar as problem-solving activities are likely to require students to engage in judgement and evaluation situations (both tend to involve 'high risk' taking), these are disliked by both 'achievers' and 'conscientious' students.
Open-ended learning activities (student-centred)	These are learning activities without clearly specifiable objectives (except those relating to scientific processes), i.e. those associated with project work or student research.	Strongly preferred by the 'curious' but not by other motivational groups who prefer clear teacher direction as regards educational goals.
Formal teaching with emphasis on information and skill transfer	Conventional 'traditional' instructional procedures, involving frontal teaching, for example: with clearly defined goals and objectives.	Preferred by 'achievers' and 'conscientious' students because low level of risk-taking is needed only.
Collaborative learning activities	Games, simulations. For specific examples see Educational Research Council of America (1971) and Percival and Reid (1976).	The majority of games and stimulation exercises devised for science education are ' interactive' and, hence, particularly suitable for learners with a strong social motivation pattern. 'Achiever' are likely to be opposed to an involvement in this type of learning activity, though.

2.5 Summary

The present chapter has dealt with three psychological factors assumed to have an effect on the performance of learners in science:

First, field-dependent/field-independent cognitive styles which may divide learners into field-independent individuals who would readily break up an organised input information and separate readily an item from its contexts, and field-dependent individuals who would find difficulties in separating an item from its context and would accept the context as it is - what differentiates the two is probably the size of the 'M-space' (whether or not it is dominated by irrelevant information) and specifically when the burden of tasks was increased on the working memory capacity (as previously discussed in chapter one in terms of the 'potential' and 'actual' working space).

Secondly, the issue of convergence or divergence plays a significant part in learning ability. Those who are convergent thinkers having thought processes which lend themselves to a narrowing down of a problem to one idea, one given end. Whilst, those who are divergent thinking in such a way that ideas may branch out, explode into new shapes and patterns.

Ultimately, the aspect of motivation allows the further division of learners into the four categories of the achiever, the conscientious learner, the curious and social learners respectively.

Thus, it can be seen that the performance of individuals in chemistry as a whole and particularly in practical problem-solving situations may be varied in accordance with such psychological factors. However, this issue needs further investigation, which will be expanded in later chapters.

CHAPTER THREE

APPROACHES TOWARDS PRACTICAL INVESTIGATIONS IN SCIENCE - PRACTICAL PROBLEM-SOLVING IN CHEMISTRY

3.1 Introduction

Having looked at learners' cognitive styles and motivations, this research now intends to focus on the importance of practical investigations in chemistry. Such practical investigations are believed to be capable of generating and developing a great deal of motivation and involvement in chemistry, by all learners of varying ability. The purpose of the present study in its practical part will be to measure the relationships between learners' cognitive styles and motivation versus success in practical investigations in chemistry.

Science was defined(94) as a conceptually organised body of knowledge about the material world. It is not only a discipline constructed of facts, concepts and principles but also a process which may clarify and unearth relationships in the universe and seek explanations and new meanings for such relationships. The purpose of science education should be to assist individuals in learning to approach their world objectively and to develop solutions for complex problems. Thus, practical investigations as activities can play a very important role in developing such concepts and skills.

Woolnough and Toh (1990)(95) emphasised that in science, teachers ought to encourage students to learn a form of science which as nearly approximates the ways in which a practising scientist works. Students must be aware of the way a practicing scientist would work through their own first hand experience which should be as important as having any other familiar experience in life. Therefore, in some part of practical work in science, it would be important for students to acquire experiences in tackling problems similar to those problems that scientists may have[96].

3.2 The Tendency of Learners Toward School Science

Educators have been trying for a long time to find out the difficulties in school science which make children, of both high and low ability, leave school ignorant of or even hostile towards science. It is worth mentioning that this problem has generated many difficulties for scientific and technological industries[97].

Achievements in school science of both capable and less capable learners have remained unpredictable. For example, Solomon (1986)[98] deduced and stated that;

"1- less able pupils can be very interested in science.

2- achievements in science might fulfill, for some able pupils, an objective other than the assuagement of interest."

Two major issues have been suggested which could greatly influence the learners' tendency toward school science, (i) the attitudes of children towards science[98, 99], and (ii) the science curriculum in schools.

In the literature, so many ideas and assumptions have been reported about the school science curriculum, which may present problems in implementation. For instance, why give all children the same science curriculum? How could science differ between schools or from individual to individual? And so on. The recently agreed assumption about what a science curriculum requires is that children are better motivated and learn more successfully when the science curriculum focuses on their immediate environment and community[97]. It is evident that the main key to successful learning lies with priority within the school science curriculum being afforded to motivation and that this may be best achieved by acknowledgement of experiences related to the everyday world of children[100]. Society would benefit best if childrens' skills and talents are fully developed.

The attitudes of children towards school science would be improved by the development of a science curriculum which took into account motivation, knowledge and an understanding of children. Science curriculum may be regarded as a vehicle for the attainment of other educational goals.

Generally, several studies[101-104] in the school science curriculum field suggest new coherent designs for the science curriculum capable of ensuring scientific literacy for all children. Moreover, it was suggested[105] that such a curriculum must contain problem-solving and investigations which could pave the road for the application of knowledge, understanding, skills and tactics to engender genuine investigations.

The trend towards practical investigations in school science must be encouraged and provoked by involving children in scientific investigations which have a certain amount of interest and knowledge.

3.3 The Role of Practical Work in School Science

The history of practical work in school science began at the end of the last century. Different views have emerged over the last century about how practical work should be conducted in school science. However, the overall view tends to be (i) enthusiasm for a greater amount of such work or (ii) may involve the dismissal[106] of practical work as time consuming.

In literature, some views have recently started to realise the important role and have perceived the educational benefit of practical work. For example, it is believed that practical work in the laboratory is an essential part of the school science syllabus in such subjects as chemistry. It provides an opportunity for learners' development from concrete situations to abstract ideas. Laboratory work could be described as a vehicle for the arousal of curiosity and an appreciation of aesthetic aspects of chemistry[107]. Three main purposes for practical work have been suggested[108]; to develop understanding of concept, to develop practical manipulative skills, and to train learners' enquiry skills.

Nevertheless, the much of practical work that has been conducted in schools is still seen as ill-conceived, confused and unproductive. It therefore provides little of real educative value. In the light of this, Hodson (1990)[109] stated that "for many children, what goes on in the laboratory contributes little to their learning of science or to their learning about science. Nor does it engage them in doing science, in any meaningful sense. We need to ask, as a matter of some urgency, how this state of affairs has come about and, more importantly, what we can do to remedy the situation."

In a critical review[109], the role of practical work in school science could be gathered into four major categories:

I - To motivate children by stimulating their interest and enjoyment.

II - To teach children practical skills.

III - To promote in children the learning of scientific knowledge as well as providing them with an understanding of scientific methods and to develop their expertise in using it.

IV - To develop certain scientific attitudes in children like open-mindedness, objectivity and their willingness to suspend judgement.

3.3.1 Stimulating Children's Interest and Enjoyment

Although, pupils' interest and satisfaction do not always increase when the amount of practical work in science is increased, pupils do regard practical work at least as a less boring activity than other methods, although it is not always enjoyable[110].

In practical work, the notion of motivation would be more valid if pupils were to be engaged in exciting and interesting tasks. Moreover, enthusiasm could reach a high level if for some pupils were to pursue their own investigations, in their own way by direct inquiry-orientated experience. Such methods are believed to be close to pupils' natural forms of thinking[111, 112]. One might therefore be critical of what is going on in almost all schools, when pupils have to investigate the teacher's problem, following the teacher recipe.

As stated, motivating children will depend on stimulating their interest, excitement and curiosity. Curiosity itself was divided[113] into four major types according to the cognitive development stages of the human being. Each type would be characterised as a particular stage of cognitive development. These types are; manipulative, perceptual, conceptual and curiosity.

Educators must realise, in designing practical work in science, that young learners would easily be stimulated by the opportunity to manipulate apparatus or to make observations, whilst old learners would need much more to be stimulated, by means such as the exploration of ideas, the investigation of inconsistencies, or the confrontation of problems. It would be unrealistic to anticipate that all learners would be motivated by same stimuli.

This fact may indicate that motivation in school science is not guaranteed by simply doing practical work unless the people who design these activities ensure that they are capable of generating interest and excitement, and allow learners a measure of self-directed investigation. It also indicates that there are other techniques needed in science lessons which may have high motivational value[109].

3.3.2 Learning Practical Skills in Science

Laboratory practical skills can be divided[109] into two sets of skills; a set of 'content-free', and a set of 'craft skills'.

In chemistry as a science subject, the craft skills would be represented in using successfully certain apparatus, such as a burette or a pipette or would be represented in using successfully certain techniques, such as titration or filtration. However, these skills were found to be untransferable to another laboratory situation like the biology one, for example. It is even difficult to use these particular craft skills in a non-laboratory situation if an application of practical skills is required. Moreover, there was some evidence that after training learners to acquire such skills for several years, some learners remain unable to perform even simple laboratory procedures[114] satisfactorily. It is worth mentioning here that the aim of this critical review of the craft skills is not to abolish such skills from being acquired by learners. Rather, it is to underline the importance of the first set of skills, the content-free skills.

Content-free skills are encouraged to be acquired by learners because they are of value in the pursuit of other learning, and such skills should be developed to a satisfactory level of competence. In terms of skill development, it is important to emphasise that the acquisition of such skills is necessary if learners are to engage successfully in practical work rather than the opposite. In other words, it would be a mistake if practical work aims to provide learners[109] only with certain practical skills.

Any practical task in the laboratory may be assumed[94] to have four phases which must be followed by learners in order to reach a solution. Each phase requires various practical skills (content-free skills) to be employed by learners to execute successfully any particular phase and to move to the next phase of a practical task. The phases with their practical skills are shown in figure 3.1. If the learner is confronted with a laboratory practical task, he would need the following skills:

I - *In the planning and designing phase* a learner will require, first, a formulation or definition of the problem. Secondly, a prediction of the result will be needed. And finally, the learner must formulate a hypothesis for investigation. In the latter stage of this phase, the learner should design his observation or measurement procedure.

II - *In the performance phase* a learner will need certain practical skills such as manipulation, making decisions, observation and reporting data.

III - *In the analysis phase* practical skills, such as putting data in tabular form, graphing them, explaining relationships and searching for generalisations, are required from the learner.

IV - *In the application phase* a learner will require predictions for the present situation, the formulation of new problems (questions) should be investigated, using the concepts and skills which are already acquired in new situations, and finally the application of these in new situations.

1.0 Planning and Design

1.1 Formulates a question or define problem to be investigated

1.2 Predicts experimental result

1.3 Formulates hypothesis to be tested in this investigation

1.4 Designs observation or measurement procedure

2.0 Performance

2.1a Carries out qualitative observation

2.1b Carries out quantitative observation or measurement

2.2 Manipulates apparatus; develops techniques

2.3 Records result, describes observation

2.4 Performs numeric calculation

2.5 Explains or makes a decision about experimental techniques

2.6 Works according to own design

3.0 Analysis and Interpretation

3.1a Transforms result into stanform (other than graphs)

3.1b Graphs data

3.2a Determines qualitative relationship

3.2b Determines quantitative relationship

3.3 Determines accuracy of experimental data

3.4 Defines or discusses limitations and /or assumptions that underly the

3.5 Formulates or proposes a generalisation or model

3.6 Explains a relationship

3.7 Formulates new questions or defines problem based upon result of investigation

4.0 Application

4.1 Predicts based upon result of this investigation

4.2 Formulates hypothesis based upon results of this investigation

4.3 Applies experimental techniques to new problem or variable

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Figure 3.1 The laboratory practical skills quoted from Lunetta (1988)[94].

3.3.3 Learning Both Scientific Knowledge and the Methods of Science

Although the teaching styles of practical work may provide a good opportunity for learning scientific knowledge, empirical evidence revealed that the teaching styles of laboratory work/discussion are important in respect to the development of laboratory skills but is not significantly superior to other teaching styles, such as lecture/discussion; lecture/teacher demonstration/discussion[(117)].

In a critical study[(118)], learners seem to perform experiments with only a rudimentary idea of what they are doing and with no understanding of the purpose of such experiments nor with understanding of the reasons for the choice of procedure.

It is believed that practical work also teaches learners about science[(109)] and its methodology. One aspect of practical work is discovery learning which is an effective way of learning science and the methods and procedures of science. However, learners would not acquire new concepts if they were engaged in unguided open-ended discovery learning activities. Such activities without guidance may lead learners to unanticipated results and to discover[(101)] an alternative science. Consequently, teachers often inform learners that they have got the 'wrong result' since such discovery is not among the teacher's goals[(119)] in the acquisition of the particular of scientific knowledge. Thus, uninformed observations do not and cannot lead to the acquisition of new concepts. Practical experience can not provide conceptual structures. Instead, the conceptual structures would give meaning, purpose and direction to practical experiences. In conclusion, theoretical consideration must precede experimental inquiry. This argument is in favour of designing a new style of learning experience[(111)] which takes into account the philosophy and sociology of science, from one perspective, and the awareness of how learners acquire concepts in science, from another perspective. Both perspectives indicate the importance of prior theorising and the exploration of existing ideas as the necessary precursor to practical investigation.

Finally, the emphasis that should be made is not on encouraging learners to learn about the methods and processes of science, but on using the methods and processes of science to investigate phenomena, solve problems and to follow interests that learners have chosen. Wherever possible, open-ended projects are recommended for learners to be engaged in during the science course, and such activities should be available to those learners who evince an interest in participating in real science[111].

3.3.4 Developing Certain Scientific Attitudes of Learners

Scientific attitudes could be defined[120] as attitudes toward information, ideas and procedures which are essential for practitioners of science. Open-mindedness, a stance which is value-free and a willingness to suspend judgement are all scientific attitudes which it may be hoped will be adopted by learners. These attitudes are transferable to other areas of concern. Unfortunately, the practical work which has already been incorporated in school science does not provide learners with access to such attributes.

Teachers must realise that children, in starting a new topic in science, often have their own scientific views which are often at variance with scientists' views. Children are often very reluctant to renounce[121-123] these scientific views. They use their own science in every day life and are capable of reproducing 'official' science when required, particularly in school. Therefore, a different view of teaching and learning procedures in school science must be taken into consideration. Such a view should be based upon developing and modifying, rather than replacing children's ideas.

An appropriate reference ought to be made in this section to the image that may encourage children to choose science. Educators ought to show children that[109] "scientists can be warm, sensitive, humorous and passionate or -more importantly- that warm, sensitive, humorous and passionate people can be scientists".

Finally, Shulman and Tamir (1973)[124] suggested a number of goals for laboratory instruction in science education. These are:

I - Arousing and maintaining learners' interest, attitudes, satisfaction, open-mindedness and curiosity in science.

II - Developing the creative thinking and problem-solving ability in learners.

III - Enhancing both scientific thinking and method like formulating hypotheses and the making of assumptions.

IV - Developing conceptual understanding and the intellectual ability of learners.

V - Developing learners' practical abilities, such as designing and doing investigations in science as well as developing their skills in observation, recording data, analysing results and interpreting results.

While Anderson (1976)[125] suggested that the goals of practical work are:

* developing learners' knowledge about the human enterprise of science as well as enhancing their intellectual and aesthetic understanding of it.
* developing learners' inquiry skills in science and make such skills transferable to other spheres of problem-solving.
* helping learners to appreciate and in part to emulate the role of scientists.
* helping learners to fertilize their appreciation of the orderliness of scientific knowledge so as to understand the tentative nature of scientific models and theories.

3.4 Problem-Solving and Open-Ended Investigations

The term investigation is defined[108] as "an experimental study that requires first-hand student participation and leads towards providing evidence that permits a question, posed at the outset, to be answered". An investigation may be executed by an individual or as a group activity. It mainly involves[126, 127] enquiry and exploration procedures. Both the laboratory as well as the library are possible places for investigations to be carried out. Thus, some investigations would be treated in the library as theoretical, whereas others would be treated in the laboratory as practical investigations.

The conclusion which may be drawn here is that investigations are not necessarily experimental. However, the practical investigations that are carried out in school science do not provide what is assumed to stimulate the growth in children's thinking. Instead, such investigations in schools only provide "recipe-following" practical activities.

3.4.1 The Aspect of Problem-Solving Investigations in School Science

Four main aspects seem to be relevant to the effectiveness of any problem-solving situations:

I - One of the vital aspects of problem-solving situations is the nature and the style of the problem-solving question which would be posed at the out set of any investigation. In a problem situation, the posed question would influence the possibilities of approaching a final solution[128, 129]. However, some problem-solving work in science identified[108] as difficult when placed in the questions' format, for example, the measurement of the surface tension of liquids.

II - Another aspect of the problem-solving situation is related to where the problem originates. The problem could be posed by the teacher, the learner or both of them. Therefore, the scope and nature of the work as well as the learners' performance could be influenced positively if learners were to recognise the source which posed any given problem (the question).

III - Learners must be aware whether a problem has been developed by the teacher, who is already aware of the solution or if it is a problem which has arisen as learner and teacher follow an inquiry and must be solved by both an interaction. It is beneficial to allow learners to understand such facts in order to encourage achievements in a problem-solving situation.

IV - The problem itself may have more than one unique solution. Some practical problems would potentially have a number of solutions and approaches. Such problems must be encouraged and promoted to enhance learners' ability to progress in open-ended situations.

3.4.2 Open-Ended Practical Investigations

This kind of practical work refers[(108)] to the outcome of any particular work when there is more than one solution or answer. The outcome of such investigations is therefore not decided before the work is undertaken. In contrast, closed-ended investigations refer to investigations when the outcome of the work is decided from the first, often before the work was undertaken. There is a third type of investigation which fills an intermediate position between closed-ended and open-ended work. Such investigations are called pseudo open-ended[(130)]. These investigations appear to be open when in reality they are intended to produce a single outcome. The pseudo open-ended investigation was considered to be convergent practical work in nature.

3.5 Lock's Diagram of Practical Work Types in Relation to Teaching Style and the Open-Endedness of the Work

From the previous section of this chapter, it becomes obvious that the teacher will have a very important role in the practical problem situation. It is therefore worth studying the effectiveness of the teacher-learner interaction with the degree of open-endedness of the investigation.

Lock (1990)[108] has illustrated in a diagram (shown in figure 3.2) such interaction with its influence on open-ended, closed-ended work. The diagram comprises two intersecting axes, the vertical one represents the continuum between open-ended and closed-ended work, while the horizontal axis represents the continuum between teacher-directed and student-centred approaches.

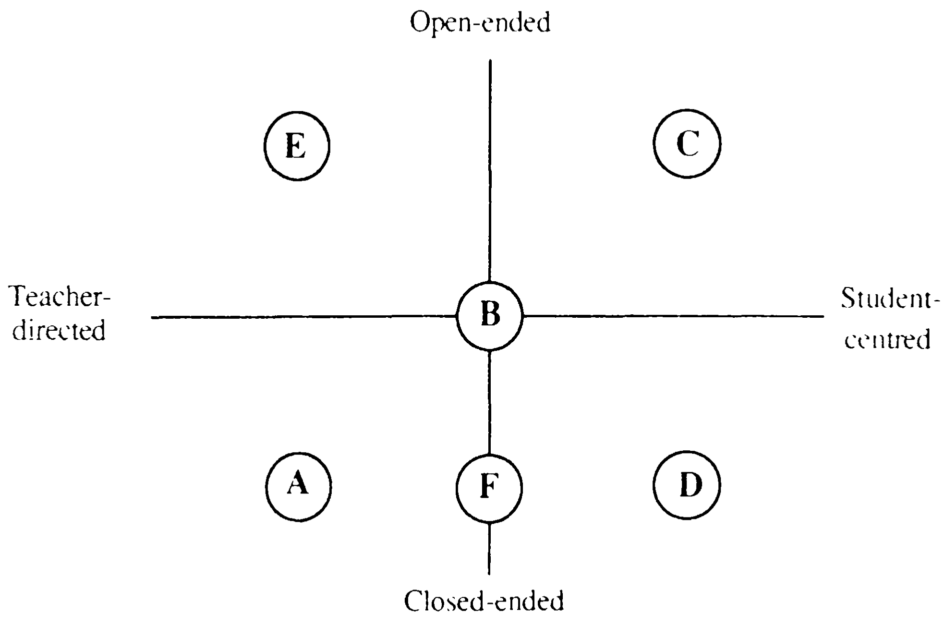


Figure 3.2 Lock's diagram to illustrate types of practical work in relation to teaching style and open-endedness of work[108].

Six positions distributed on all over the diagram represent different styles of practical work in relation to the position which they occupy. In general, the practical work located at the lower half of this diagram refers to that work which follows any theory or hypothesis that has been previously presented to learners, in order to confirm the theory or the hypothesis practically:

I - Position A: This kind of practical work is the most familiar one in school science. For example, when the pupil is asked to show that pure water will boil at 100°C. The outcome of such an experiment (practical work) is unique and determined by the title. The procedure might be decided by the teacher or, in some circumstances, it is the teacher himself who would carry out such an experiment.

II - Position F: The practical work shows in this position a balance between the teachers and pupils input. Pupils would be allowed to carry out an experiment which was designed by themselves, but the teacher may then interrupt suggesting another approach to the experiment which he assumes to be superior and ought to be adopted by pupils.

III - Position D: This kind of practical work is not so often used in school science. A teacher may ask his pupils to plan and carry out an experiment or a series of experiments in order to show that, for example, snow, ice, and steam are all the same substance. This kind of practical work is considered as problem-solving since pupils are not told how to carry out such an experiment. Nevertheless, experiments like that mentioned are located at the closed-ended position in the diagram.

IV - Position B: The practical work involved in this position is the pseudo open-ended work (closed and open-ended investigations). It is called, sometimes, a guided-discovery approach to practical work. For example, the teacher poses his pupils a problem in which pupils have to ask several questions in order to lead them to an interpretation of the results that they have obtained. The teacher knows the outcome of the problem but his pupils do not. Such an environment has been encouraged elsewhere[121] as a useful device in school science.

V - Position E: This type of practical work is not so often found in school science. It is a practical problem which is teacher-directed but open-ended. The main reason behind not using such practical work in schools is that teachers do not want an undesirable outcome to emerge when it may be achieved. A wide range of solutions could be obtained sometimes from this kind of work. However, such practical work would be beneficial in learning certain techniques or experimental methods. For example, pupils are given a liquid which contains two other chemicals, they were asked to separate these chemicals from each other. The teacher may provide pupils with a certain procedure to tackle the problem, such procedure is therefore called recipe-following. Such activities aim to let pupils acquire a degree of familiarity with the techniques that have been employed. "In such situations the collation, evaluation and interpretation of results can be devolved to the students without serious worries of whether misconceptions are being fostered or reinforced"[108].

VI - Position C: The practical work in this position is not uncommon in school science. This kind of practical work is considered as an ideal type for open-ended and problem-solving principles. It may involve everyday life problems of pupils and may not be novel for them. However, such practical work is a new element in school science, it has been there since the early 1970s[131]. But, a word must be said here and that is the design of such work requires much care from teachers and educators compared with other types of practical work.

Generally, in the school science curriculum, there is enough room for all styles of practical work (located in all positions) to be exercised. Building on this, it would therefore be important to allow pupils to gain a variety of experiences through trying out different styles of practical work. Even greater benefit could be obtained if teachers were to inform pupils of the varied nature of investigative work and therefore pupils would not become anxious about what they are learning.

Some types of practical work which are located at certain positions could easily be moved to other positions. For example, the experiment involving pure water (boils at 100°C) which was located at position A but could be moved into position D, if teachers were to ask pupils to determine the boiling point of pure water independently without any instructions. Teachers may control the movement of different practical work styles from a position into another one, moving then in accordance with whichever is more beneficial for the training purposes of their pupils. However, it is worth mentioning that it would not be impossible to have practical work which fits more than one position in Lock's diagram.

3.6 The Teacher/Learner Control over Practical Work Elements

Could it be that teacher-directed practical work is more important than learner-centred practical work or would the opposite be true? Has the cooperative activity shared between the teacher and the learner any advantages for science education or not?

Such questions must be treated tentatively in science education. As seen earlier, every kind of practical work has particular benefits so that some elements in any practical investigation would benefit best if they were teacher-directed, others if they were learner-centred, whilst the rest of the elements would be most effectively used in cooperative activity shared between teacher and learner.

Lock (1990)[108] has given seven elements involved in any practical work. These are; area of interest, statement of problem, planning, determination of strategy, carrying out of practical work, collation of results, and evaluation/interpretation of results. Lock drew a variety of situations in which control over such elements is divested in learners or teachers. These situations are shown in table 3.1.

Table 3.1

Hypothetical practical work situations identifying student or teacher control over elements of the work[108]

	Situations with variety of teacher/Student control over elements involved						
Elements involved in practical work	1	2	3	4	5	6	7
Area of interest	T	T	T	T	T	T	S
Statement of problem	T	T	T	T	T	S	S
Planning	T	T	S	S	S	S	S
Determination of strategy	T	T	T	S	S	S	S
Carry out of practical work	T/S	S	S	S	S	S	S
Collation of results	T	S	S	S	S	S	S
Evaluation/interpretation of results	T	T	T	T	S	S	S

In brief, studying those elements of the practical work versus various situations, a teacher's control will be seen overwhelming across situation 1. In situation 2, the learner may be given the opportunity to train and develop his skills in carrying out the experiment as well as given control over the collation of results. Situation 3 may require a greater contribution from learners by discussing, perhaps in small groups, their ideas with the teacher for a final single strategy derived mainly from the teacher himself with some contribution hopefully from one or two learners. This approach is good for planning skills but it has not practically a great advantage because it is often carried out in a pencil and paper mode. It could be stated here that the design of such experiments would be dominated by the teacher's suggestions determine the learners' interaction with the materials/trial experiments such instructions influencing the proposed designs.

Situation 4 allows learners to carry out their own designs and ideas. Although, such practical work may result in some inaccurate or irrelevant conclusions, with teacher control over the evaluation of results none of this would matter. Situation 5 gives learners the opportunity to interpret the outcome and results of all experiment. Therefore, it is possible that learners may acquire an alternative understanding to that expected during the work because this situation leaves open the interpretation of results to the learner. These alternative ideas could be reinforced by lack of teacher control. However, this procedure, as a consequence, would contribute, to some extent, in understanding certain concepts of practical work.

Situations 6 and 7 are the most extreme situations that would be under learners' control (learner-centred). Situation 7 would even give learners an opportunity to choose an area of interest (topic) for practical work, while situation 6 may allow teachers to chose any particular topic for investigations. Learners in situations 6 would therefore get advice, and consult with teachers before starting the actual practical work under the learner's control.

It seems prudent to mention that the above situations are important in school science with different effectiveness and acquisitions of skills and concepts. However, in recent years, educators have begun to encourage practical work under learners' control[132, 133] in school science.

Learner-centred practical work demands a larger amount of effort, requiring more time than conventional work. The science curriculum must also be assessed under certain circumstances to focus on those particular issues which regard learners as an important body - such issues must be allowed primacy in the curriculum. Moreover, specific training would be needed for the designers as well as the participators in the science curriculum to facilitate the adoption of practical work.

3.7 How to Make the Practical Work More Open-Ended?

Lock (1990)[108] suggested five steps towards making any practical work more open-ended. He specified five questions shown in table 3.1 as steps towards open-endedness and which are identified by the bars labelled A to E. These steps (bars) can be characterised by the questions below and may make practical work more open-ended and so more learner-centred;

" A - Who defines the area of interest?

B - Who states the problem?

C - Who does the planning?

D - Who decided on the strategy used?

E - Who interprets the results? "

It is noticeable from table 3.1 that one bar has been left unidentified because it represents the break between teachers or learners control over carrying out the practical work as well as the collation of results, which has no significant implications for making the work more open-ended or learner-centred.

In some circumstances, Lock's steps form a hierarchy as shown:

(base) C $\longrightarrow$ D $\longrightarrow$ E $\longrightarrow$ B $\longrightarrow$ A (apex)

Teachers seem to be less reluctant to depart from some aspects near the base of this hierarchy, like C and D (planning, determining strategy), as such departures evince a move from teacher to learner control. However, Lock has emphasised that such an assertion cannot bear close scrutiny. Learners can participate in identifying an area of interest (A), and at the same time, teachers can set up the strategy which would be used (D), in addition to the statement of the problem (B).

If more open-ended, learner-centred practical work were required in science, answers to Lock's questions (steps) should be 'learners' or usually 'learners'. Nevertheless, in planning lessons, if one or two answers to such questions have been 'learners', it is still important to go ahead with these situations for a certain benefit i.e. the lessons will be focused on the skills involved in the particular aspects which dominated those questions, for example, planning out or deciding between a range of different strategies in order to determine which strategy or strategies are most relevant.

3.8 Mini-Projects as a Model of Problem-Solving Activity

Research has been conducted[134] at the Centre for Science Education, the University of Glasgow which aimed to invent a design for practical work activity at Scottish secondary schools (Standard Grade Chemistry Courses). The outcome of this work was called *"Mini-Projects"* in chemistry.

The main reason behind the production of such work is to engage pupils in creative experimental work that would assist them in improving chemical skills, techniques, knowledge and understanding towards chemistry in the syllabus as well as the chemistry in nature.

Hadden (1990)[25] claimed that mini-projects had an extensive motivational effect on young pupils. As was stated before, teachers should stimulate pupils' creativity by engaging them in activities which have motivational effect. Therefore, mini-projects may add a significant teaching tool to a teacher's professional repertoire. The use of mini-projects may require a teacher's persuasion skills to encourage the motivation of pupils. In addition, mini-projects are essential in training the thought processes of pupils when they are asked to conduct scientific methods.

3.8.1 The Description and Design of Mini-Projects

The one hundred chemical projects that constitute mini-projects have been presented in two accessible booklets. The first booklet contains 60 projects[134], while the second one consists of the 60 projects of the first booklet plus another 40 projects[135]. Each project has been submitted in two sheets, a pupil's worksheet and a set of teachers' notes sheets, the former comprises of:

I - A statement of the problem that has to be solved by the pupil.

II - The essential apparatus or chemicals for introducing the problem to the pupil, such as a test tube of unknown solution or a chemical sample in a beaker.

III - Other apparatus would be supplied for pupils on request. This is in order to create a problem, because apparatus may express the physical aspect of a problem and may provide the pupil with some visual guidance.

IV - A space in the sheet after the statement of the problem for pupils to re-write the problem in their own words.

V - Another space for their initial plan to tackle the problem.

VI - A space for pupils to write how they intend to carry out the work.

VII - The remaining space in the pupils' worksheet (the back of the sheet too) is intended for the pupil's conclusions, results, written method and diagrams or pictures if such are required.

The teachers' notes sheet comprises of:

I - A list of apparatus which is needed or may be needed by pupils during the experiment.

II - The possible strategy of solution to the given problem, which could be used as a teaching guide.

III - Some advice for safety precautions if any.

The design of each project in the mini-projects booklet presents[25] a problem which has carefully been set up in order not to give any indication about its procedure. It requires practical work "at the bench". Pupils must use their various skills, knowledge and techniques which are acquired during the chemistry course at school to tackle such problems. Several types of problems are involved in the design of the mini-projects booklet e.g. open-syllabus based; closed-syllabus based; open-everyday in nature, closed-everyday in nature and real world simulation problems.

Each individual problem may possibly be solved within an hour including time for pupils' writing up. Mini-projects activities involve open text books, data books and pupils' notes.

3.8.2 Examples of Different Problems Involved in the Mini-Projects Booklet

As stated in the past section, there are five types of problems involved in the design of mini-projects. These are:

I - Open, syllabus based problems which may have more than one unique method for the correct solution. For example, the participant may be asked to find the best way of keeping the zinc metal from corroding in the blue solution. (Zinc and copper [II] sulphate solution provided, nail varnish, paint, various metals, and so on are available).

II - Closed, syllabus based problems which should have a unique method for the correct solution. For example, the solutions in test tubes 1, 2, 3 and 4 contain barium chloride, copper [II] sulphate, dilute sulphuric acid ("hydrogen sulphate acid") and sodium chloride but not in that order. You have to find out which test tube contains which solution. (No other chemicals are issued).

III - Open, "everyday" based problems which involve domestic materials such as household liquids or powders. These problems may have more than the unique method for the correct solution. For example, you have to find the best detergent solution for car windscreen. (Various detergents are provided, oil, grease, soil, salt, microscope slides and so on are available).

IV - Closed, "everyday" based problems which involve domestic materials such as household liquids or powders, but which should have a unique method for reaching the correct solution. For example, you have to find the volume of air contained in a piece of Aero chocolate. (Apparatus for melting, and measuring cylinders available).

V - "Real world" simulation problems which are similar to those problems that professional chemists may have to deal with, such as corrosion or pollution. For example, a new ore has been discovered. You have been asked to find if any valuable metals or gases can be produced from it for the chemical industry. (Provided: "Ore" which is a mixture of $CaCo_3$ and $CuCo_3$ set with a little portland cement and cement-colouring agent available : Various reagents, flame test apparatus, and so on).

3.8.3 The Consistency of Mini-Projects with Educational and Psychological Findings

The work of mini-projects has been chosen for the practical part of the present research as a body of chemistry in order to study pupils' performance in such work compared to their classification in psychology (what they have scored in tests related to some psychological factors which have already been discussed in the previous chapter).

It was found(1) that some learners who, while being classified as 'weak' in chemistry, according to their scores in conventional chemistry examinations, may be able to perform well in activities which involve practical problem-solving in chemistry, especially in tasks which required the use of the learners' creative thinking.

In experimenting with mini-projects in schools, it was found(25) that 'weak' learners did astonishingly well in such projects. In fact, this most closely approximates the researchers' previous findings and therefore mini-projects could be used in the present study as an ideal means of presenting chemistry at the bench.

As a body of chemistry, mini-projects are frequently compatible with what this research requires for its practical part. Hadden (1990)(25) reported "pupils who had been assessed as low performers in traditional written examinations in chemistry, often did surprisingly well in practical problem-solving. (The reverse was also true in some cases). It may be that the use of mini-projects allows some 'low ability' pupils to perform better in a dimension which is more compatible with their inherent gifts. The lack of transferability of theoretical knowledge acquired by 'high ability' pupils to the realm of practical application may also have been exposed".

The philosophy of mini-projects concurs with other studies in psychology and education. Each project is a simple statement which would avoid any overload of information[2]. Moreover, each project can be executed in an hour, therefore, it is short in time which may allow frequent use by pupils[136].

Finally, it is worth mentioning that mini-projects practical activities aimed to find a niche for themselves in the Standard Grade Chemistry course in Scottish secondary schools.

3.9 Some Views of How to Assess Practical Work in Chemistry Science

In any particular topic in chemistry, if pupils have conducted a practical investigation, they must be then given a reliable indication of what has been achieved. In other words, an assessment should be made in order to promote pupils' learning in such a topic[137].

From reading in literature, it is evident that the most important feature of the practical work which makes it different, in some measure, from non-practical work is that the practical work involves both manual and intellectual abilities[138, 139]. It involves practical skills (manual) which would be acquired throughout the actual practical work in the laboratory as well as during training and practical intellectual abilities which concern the understanding of any particular subject in science.

In some literature, the manual and intellectual abilities are defined as processes skills[140, 141] which may be divided into 'macro process skills' and 'micro process skills'[142], these will be explained later in this chapter.

In the following overview, the researcher intends to summarise the assessment of manual skills. However, greater emphasis will be given to that other part of assessment which concerns the intellectual ability of pupils in doing practical investigations.

3.9.1 Manipulative Skills in Practical Chemistry

Manipulative skills could be identified as skills which are involved in the form of constructing apparatus such as using a burette, or using a pipette, or handling a gas syringe, or setting up a distillation apparatus.

To assess any particular practical skill[143], two main factors should be taken into consideration; (i) the components of that practical skill; (ii) and the achievement criteria which will be used as reference standards in the general assessment operation.

Buckley and Kempa (1971)[144] broke down the area of manipulative skills into sub-areas in order to specify for each sub-area generalised performance criteria. A breakdown analysis of manipulative skills is shown in table 3.2.

Reading table 3.2, it is possible to comprehend that some major operation criteria were set up (in the table) relevant to their assessment. Each general criterion will require further amplification in accordance with any particular practical task that would be carried out in the laboratory.

There are three different modes of assessing manipulative skills:

I - One of the most relevant tasks in assessing manipulative skills by direct observation is to form a general impression of a pupil's performance in the laboratory, by noting his strong and weak performance points, and the teacher eventually may translate the impression gained into a point on the *1-5 rating scale*. This kind of assessment may be described, to some extent, as a subjective assessment and sometimes is called the open-ended mode[144] because it depends upon personal judgements. Subjective judgements are usually varied as a result of inaccuracies and the personal biases of the assessors.

Table 3.2

A breakdown analysis of manipulative skills (Buckley and Kempa, 1971)[144]

Component	Genealised criteria/Performance features
Methodical working	Correct sequencing of tasks forming part of an overall operation Effective and purposeful utilisation of equipment Efficient use of working time Ability to develop an acceptable working procedure on the basis of limited instruction
Experimental technique	Correct handling of apparatus and chemicals Safe execution of an experimental procedure Taking of adequate precautions to ensure reliable observations and results
Manual dexterity	Swift and confident manner of execution of practical tasks Successful completion of an operation or its constituent part-tasks
Orderliness	Tidiness of the working area Good utilisation of available bench space Organisation in the placing of equipment used

II - The second mode in assessing manipulative skills is by using a check-list which comprises of different performance criteria that would assess a pupil's overall practical skills. It aims to obtain an objective assessment since any check-list would contain many specific points about manipulative skills involved in any particular practical task. Nevertheless, objective assessments of manipulative skills are fairly difficult to accomplish.

III - The third mode in assessing manipulative skills is called an 'intermediate' mode. It is intermediate between the two aforementioned modes above of assessment. In this mode, "the subjective impression-based form of assessing skills is retained, but it is applied to the main components of the manipulative skills domain (as shown in table 3.2), instead of to the practical task as a whole". Examples from each mode above are exhibited in figure 3.3 (I, II, III), quoted from Eglen and Kempa's (1974)[143] study.

Grade awarded

Major manipulative abilities looked for in the operation

Features in the student's performance used for the grading

Figure 3.3 (I) An example of the open-ended schedule.

a - Methodical working — GRADE

e.g. in the washing of glassware; in the transfer of solid and of solution; in the processes of rinsing and diluting; in the stirring and dissolving operations.

Features in the student's performance used for the grading

b - Experimental technique — GRADE

e.g. that used in the handling of glassware and of materials; in the operations of dissolving, transfer, washing and dilution.

Features in the student's performance used for the grading

c - Manual dexterity — GRADE

e.g. in the general manner of performance and in the completion of the task.

Features in the student's performance used for the grading

d - Orderliness — GRADE

e.g. in the utilisation of bench-space and the organisation of equipment.

Features in the student's performance used for the grading

Figure 3.3 (II) An example of the intermediate mode.

Section A - Dissolution of the solid water	YES	NO
a.1. Were the beaker and the stirring rod initially washed with distilled water?	O	O
a.2. After the transfer of the solid into the beaker, was the weighing bottle rinsed out with water?	Y O	N O
:		
:		
:		
b.3. Were all operations carried out in a manner which did not conflict with the quantitative nature of the exercise?	Y O	N O
Section B - Transfer and dilution of the solution		
a.1. Was the overall working sequence during the transfer of the solution from the beaker into the volumetric flask logical and acceptable?	Y O	N O
a.2. Was all glassware washed with distilled water, prior to use?	Y O	N O
a.3. Was a funnel used when transferring the solution from the beaker to the flask?	Y O	N O
:		
:		
:		
d.2. Was apparatus no longer in use removed from the immediate working area?	Y O	N O

Figure 3.3 (III) An example of the check-list mode.

3.9.2 The Cognitive Processes in Practical Chemistry

First of all, it is prudent to mention that there are several explanations and suggestions for how to assess the pupil's work and report progress doing a practical investigation. Several process skills (cognitive and manipulative processes) would be involved in tackling any practical investigation and therefore these skills need to be assessed. Moreover, a pupil is more often asked to write his report about the practical work which he or she has done, and again this report needs to be assessed.

3.9.2.1 Assessing Chemical Process Skills

In general, science process skills could be divided into the ability to recognise and describe the nature of the problem which is termed 'macro process skills', and the ability to analyse the problem into its component parts which is termed a 'micro process skill'[142].

A possible way of structuring chemical process skills is to consider an idealised chemical problem. Three broad phases could be involved[145] in such problem; the planning phase, the implementing phase and the concluding/evaluating phase. Each phase comprises of a large number of process skills and major subdivisions are provided for assessment purposes. The interaction between the three phases is seen in figure 3.4[146].

In another study, Swain (1989)[142] has divided the way in which any problem could be tackled into three broad phases; "(a) the pre-operational phase (the design or planning phase), (b) the operational phase (the implementation phase), and (c) the post-operational phase (the concluding or evaluating phase)".

In figure 3.4, the planning phases are divided into a number of subskills on which practical problems might have some bearing. A pupil should show his progress in such skills and would be assessed later on by his teacher. For example, the skill to[146]:

I - Understand which procedure or technique is needed to be adopted.

II - Select a procedure out of several possible other procedures or techniques because of the nature of the problem and the practicability which includes safety aspects and resources.

III - Draw and indicate a list of apparatus or chemicals which are needed to tackle such kind of problem.

IV - Indicate how he intends to employ such apparatus or chemicals in the experiment.

V - Provide the sequence for the use of such chemical or apparatus.

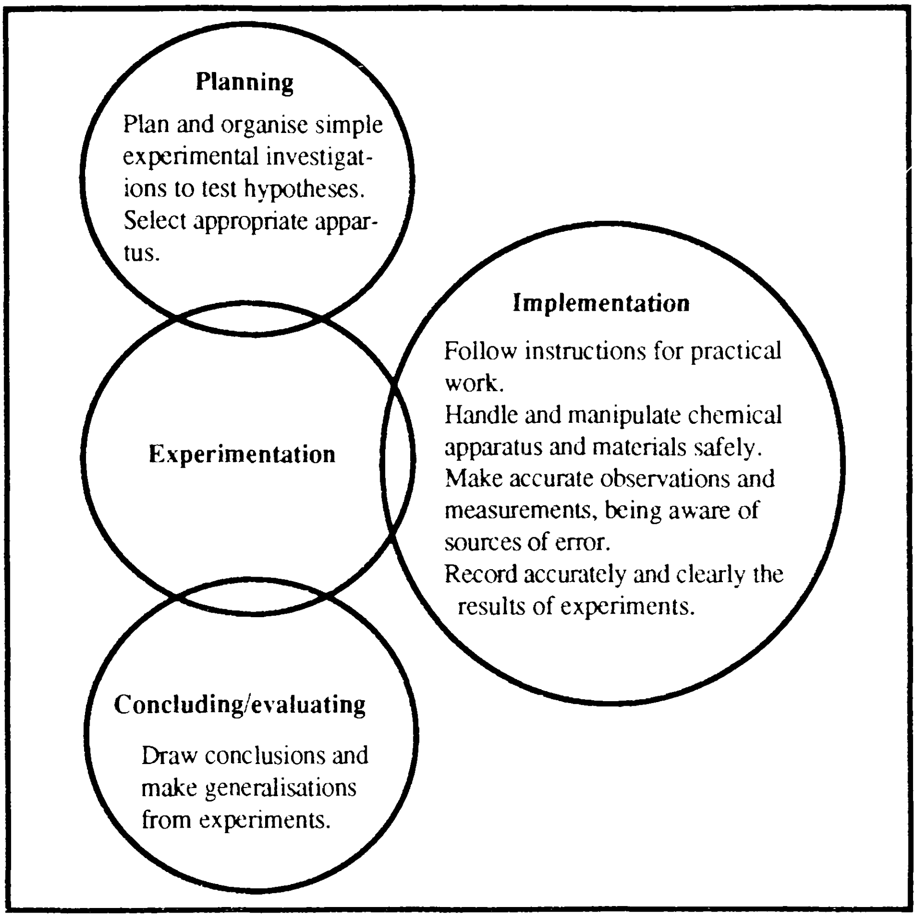


Figure 3.4 The three interacting phases for any idealised experiment.

In the implementing phase, the pupil needs to show his ability to follow and comprehend instructions relating to the implementation of practical procedures. Observational methods would be appropriate, to some extent, for the assessment of this phase. It is important here to mention that almost all skills involved in this phase are considered to be manipulative skills which have been discussed in the previous section. However, a method[(146)] was suggested for the assessment of such a criterion, is by using a *10-point scale* and by providing *discriptors*. A 10-point assessment scale is shown in table 3.3 (quoted from Swain's 1988[(146)]study).

Table 3.3

10-point assessment scale for following instructions

10	Follows instructions, linear or branched, given in any format for an experiment with several distinct stages, without help.
8	Follows a set of linear instructions given in any format without help.
5	Follows single step instructions, some assistance may be requested and given.
3	Follows single step instructions often in a verbal format. Teacher contact time with pupil is high.
1	Unable to follow instructions without maximum assistance.

In the concluding/evaluating phase, the pupil will be required[146] to process and interpret results, predict and draw conclusions. Also, the pupil must evaluate the validity/reliability of procedures in accordance with the experimental evidence.

To be more precise, this phase needs the following skills from pupils:

I - How to calculate numbered values from data, comparing to other known data and the pupil must then be able to translate the information from one form into another.

II - How to deduce data from graphs, tables, drawings..etc.

III - How to make qualitative and quantitative conclusions about interrelationships within data.

IV - How to structure generalisation or explanations and how to make predictions based on data.

V - How to evaluate the validity/reliability of procedures and results in accordance with the experimental evidence that the pupil has.

IV - How to draw eventually final conclusions and how to report on the interpretation of data. Table 3.4 (quoted from Swain's 1988 [146] study) shows a possible form (possible descriptor) to be used for the assessment of this phase.

Table 3.4

Drawing conclusions and making generalisations

10	Draws conclusions from both qualitative and quantitative data and offers explanations. Evaluates procedures and results and suggests alternatives without help.
8	Draws conclusions from both qualitative and quantitative data and offers some explanations. Makes attempts to evaluate procedures and results without help.
5	Draws some conclusions from both qualitative and quantitative data and offers single explanations. Little attempt to evaluate procedures and results. Requires help occasionally.
3	Draws few conclusions from data. Few explanations offered. Little understanding of evaluation. Usually requires help.
1	Can only draw conclusions with maximum help.

In designing scientific investigations, educators would be able emphasise any particular phase required. In other words, looking at the whole individual investigation in general and dividing its procedure into three phases, varied scales could be allocated on the three phases of the practical investigation in accordance with the emphasis required for any particular phase. For example, the maximum scores might be:

Planning	3		Planning	4
Implementing	4	**or**	Implementing	3
Concluding/evaluating	3		Concluding/evaluating	3

It is not the aim of the present study to illustrate how each sub-skill or sub-division of chemical process skills should be recorded in teachers' marking books. However, Lock and Wheatley (1989)[147] have suggested four systems in which pupils performance on process, skill and criterion may be recorded for age 11 onwards. These are; a task-centred system; a skill-centred system; a criterion-centred system; and a two-stage system. In another study, Lock and Wheatley (1989)[148] delineate another means of recording pupils' performance, but in this method the assessor is the pupil himself.

Ultimately, the division of any experimental work into the planning, implementing and concluding/evaluating phases does not mean that such division is a unique agreed division, nor does it mean that all literature readily agrees about dividing the experimental work into certain three phases. In stead, there are various studies found[147, 148, 149] in literature showing different phases or even different terms for such phases in a division of the practical investigation, and of course various skills will be involved in any particular proposed phase.

3.9.2.2 Assessing the Written Reports of Chemical Investigations

In a laboratory, the final procedure that pupils may encounter in doing practical investigations is to submit a written report explaining the plan, procedure, results, and conclusions. For the purposes of assessment, three types of report sheet were suggested[150] on which teachers asked pupils who had performed a particular investigation to describe what they had done. These are:

I - *The open-ended (uncued) report sheet*: This type was designed to allow pupils to report what they intend to say freely[151] and without any interference from the teacher. It should minimise restrictions in articulating what pupils have done. This type of report would provide pupils scope for creativity and diversity as it allows them to express freely their procedure and achievement. However, this type of report may not help pupils who are less articulate or those who have difficulties in writing reports because of their lack of language skills.

II - *The specific focused (fully cued) report sheet*: This type was designed to focus on a particular investigation concerned. It does allow pupils to report things which are not required. In other words, pupils will be provided with a list of questions which ask them for specific responses. Some of these questions are generic and may be repeated in other tasks or may be similar across different investigative tasks. Other questions are not task-specific and will not be repeated across tasks. Pupils who are convergent would favour such a type of report sheet. Building on this, fully cued reports could be ideal for the achiever and conscientious pupils in accordance with their motivational traits. "It should also cater to those who are less expressive by nature or those with a poor command of the language"[150].

III - *The broad focused (partially cued) report sheet*: This type was designed as an intermediate style between the other types. It is generalisable and applicable to a wide range of investigations, yet "provides some form of structure upon which pupils are able to make up a sufficiently coherent report"[150]. The partially cued or 'broadly cued' report is asking the pupil to write his account under six sections which would outline the overall stages comprising a typical investigation. These sections are; preliminary trials; planning;

performing; communicating; interpreting; and feedback decisions. Such a type of report would suit the less articulate pupils as it would provide them with a report sheet that focuses on the broad areas of decision-making when pupils are performing practical investigations. It would suit those pupils who can express themselves but need some guidance to carry on in their practical work. This type of report sheet is shown in figure 3.5.

Toh and Woolnough (1990)[150] believed that the broad focused report sheet is applicable to a wide range of investigative tasks. Such a report scored high correlation coefficients with the checklist scores and therefore Toh and Woolnough suggested its reliability in ascertaining pupil performance in practical tasks. "Most encouraging of all were the results for the 'broad cued' report sheet. These consistently correlated most highly with the checklist scores, with a Pearson Product-Moment Correlation Coefficient of 0.8".

Toh and Woolnough (1990)[150] have prescribed such reports for use in place of the much more laborious one-to-one observational checklist. It could be designed[151] to match the general criteria of the different GCSE syllabia, and could provide a fruitful common basis for teacher moderation and convenient evidence for the examining boards.

However, the broad focused report sheet is found[151] to be unsuitable to meet the needs of pupils who have difficulties in expressing themselves in writing. Also, it does not meet the requirement of the higher levels of attainment in the national curriculum science since the latter would require pupils to write extended reports for practical investigations and with an emphasis on using of their own words.

REPORT SHEET

(You may use the blank space on the reverse side of this sheet if you find the space provided for any of the sections insufficient)

PRELIMINARY TRIALS	Describe any preliminary trials you did before starting on the investigation.
PLANNING	Describe your original plan, and any changes if you modified the original plan during the course of the investigation.
PERFORMING	Describe what you did. What were the measurements you took? What did you do to ensure the measurements were accurate?
COMMUNICATING	Make a clear record of the readings of your measurements.
INTERPRETING	What conclusions did you draw from your results? Describe why you reached that conclusion. How confident are you about your interpretation? (explain any uncertainty you may still have)
FEEDBACK	If you were to do this again, how would you change the investigation?

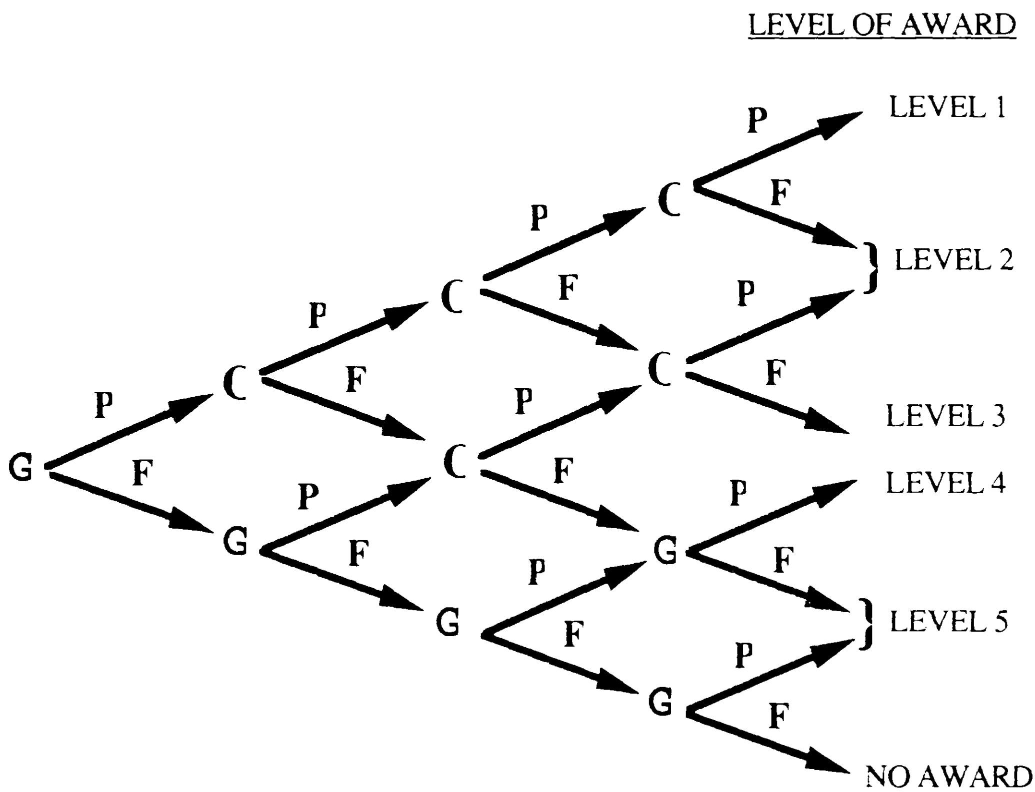
Figure 3.5 The broad focused (partially cued) report sheet .

3.9.3 The Assessment of Mini-Projects

Because mini-projects are a new practical element proposed for Standard Grade Chemistry at Scottish secondary schools, the assessment of such projects is still in progress. However, it is hoped[152] that assessors, in assessing mini-projects, will place special emphasis on "assessing abilities which are peculiar to it rather than merely repeating assessment procedures carried out elsewhere".

The researcher of the present study also intends to work out a method (a proposed method) for assessing mini-projects. This method will be discussed in the practical part of the study (future chapters), employing results from psychology for the assessment purposes.

Nevertheless, in an unpublished study[152], an assessment method for mini-projects was proposed for the benefit of the Standard Grade Chemistry. The main procedure of this method is to categorise mini-projects as 'General' and 'Credit' according to their level of difficulty ('open-ended' projects should not be included). Each pupil is required to solve four mini-projects starting with a simple one (General). The four projects were suggested[152] to be carried out within the two years in which practical work in chemistry may take place. The words 'pass' and 'fail' are suggested as choices or decisions for the pupils' achievement in the projects. The scheme that would indicate pupils' progress in tackling mini-projects is shown in figure 3.6. The teacher will have a copy of the diagram (figure 3.6) for each pupil. He may tick 'P' (pass) or 'F' (fail) in accordance with the pupil's achievement in projects.



C = Mini-project of 'Credit' standard
G = Mini-project of 'General' standard
P = Pass
F = Fail

Figure 3.6 The proposed scheme for the award of Grades[152].

3.10 Summary

This chapter was intended to highlight the importance of doing practical problem-solving investigations in chemistry by school pupils. Working in a laboratory must not be recipe-following, but must aim to bring to fruition pupils' creativity, imagination, self-determination, and practical and intellectual skills. Motivation in school science is not guaranteed by simply doing practical work, therefore, educators should provide such work with interest and excitement, and allow learners a measure of self-directed investigation.

Unfortunately, the practical work in chemistry which has been conducted in secondary school science is still recognised as ill-conceived and unproductive.

Therefore, a new look at the construction of school's practical chemistry syllabi would be essential in order to underline what is required, and what schools' learners, in terms of motivation, may require.

A practical investigation could have four phases to reach a solution; the planning and design phase; the performance phase; the analysis and interpretation phase; and the application phase. The learner is required to use his intellectual and practical skills in order to tackle any practical problem passing through those four phases.

Open-ended, closed-ended, and pseudo open-ended are three different types of practical investigations which have been named according to their outcomes (open, closed, or both). Opportunity for open-ended practical investigation must be given in the chemistry syllabus of school science to develop learners' knowledge and understanding.

Mini-projects are a new practical element in school chemistry aimed at the stimulation of learners' motivational traits towards creativity, and are essential for thought processes. Such projects are more likely to be student-centred and vary from open-ended to closed-ended with a connection to everyday based problems and real world simulation problems. An important feature in mini-projects is that the learners themselves take control of experiments, bringing a new mode of practice in problem-solving chemistry.

Various views, in assessing practical problem-solving in chemistry, can be found in the literature. In general, two different sets of skills should be employed by learners in any practical problem situation; the manipulative processing skills; and the intellectual processing skills. Once again, various assumptions can be found in assessing such skills these include the assessment of learners' written reports. This present study, however, intends to apply a genuine assessment method for mini-projects for the purpose of this research.

CHAPTER FOUR

THE METHODOLOGY WHICH IS EMPLOYED IN ORDER TO MEASURE THE PUPIL'S PSYCHOLOGICAL FACTORS

4.1 Introduction

In this chapter, attention will be paid to the test methodology which has been employed in the present research at the psychology phase.

Several methods were used in psychology in order to test Field-Dependence/Field-Independence, Convergence/Divergence, and Motivation of learners. The researcher, however, intends to apply some methods that have been developed and modified by himself or by other researchers at the Centre for Science Education at Glasgow University. The results of using such methods and measurements on the research sample will be discussed in the next chapter.

The research was conducted upon Standard Grade pupils at the secondary level of education in Scottish schools while they were doing the chemistry course as part of the Standard Grade requirements.

4.2 The School Pupil Sample

In 1989 an attempt was made to select a sample of pupils from Scottish secondary schools. The intention was to find out which schools have been involved in a new chemistry course {replacing the O'Grade (O'level in England)} which is called *Standard Grade Chemistry.* The schools which were chosen are in the Central Region of Scotland. Table 4.1 shows these schools with the number of participants. It is worth mentioning here that the original total number of the sample was above 300 pupils, but due to the difficulties of getting all of them to follow and complete every single procedure applied in the research, only 217 pupils eventually made up the total number since they had fully completed the procedure for the completion of the present study.

Table 4.1

The schools selected as the sample for the study

Selected schools	No. of pupils
Denny High School	53
Lornshill Academy	49
Stirling High School	44
Bannockburn High School	30
Wallace High School	41
Total	217

The first experiment which was carried out in schools, after selecting a sample for this research, was the measurement of some psychological factors. The researcher intended to keep a record for each pupil displaying his/her performance and achievement in every single procedure applied.

4.3 The Measurement of Field-Dependence/Field-Independence

The first test applied to the sample is called the *Hidden Figures Test* (HFT). It aimed[(1)] to measure the pupils degree of field-dependence/field-independence. A sample of this test is to be found in the appendix 1.

The basic purpose of this test is to place pupils along a continuum ranging from very field-dependent to very field-independent. This distribution was then divided into three categories:

I - Field-dependent pupils who may be defined as pupils who would find difficulty or be unable to discriminate a required item from its context.

II - Field-independent pupils who may be defined as pupils who would be able to discriminate a required item from its context. It is possible to say that field-independent pupils may separate the 'signal' from surrounding distracting 'noise' with greater ease than field-dependent pupils who may encounter difficulties in such a process.

III - Field-intermediate pupils who may be located in between the above two categories along the continuum ranging.

4.3.1 A Description of the Hidden Figure Test (HFT)

This test has been designed depending upon Witkin's work[15, 27, 29, 30]. The HFT comprises of 18 complex figures, apart from another 2 figures used as examples. There are 6 simple geometric and non-geometric shapes which are embedded in the 18 complex figures (one simple shape in each complex figure) and pupils must isolate these shapes.

2 Examples are used in the first two pages of the HFT booklet. 6 Simple shapes (geometric/non-geometric) are located in the third page of the test booklet as a specimen of the type to be found. Pupils are required to find a hidden simple shape in each complex figure. They must then outline and trace it in pencil or pen against the lines of the complex figure.

4.3.2 What Conditions in the HFT should be Followed?

There are certain conditions in the HFT which need to be followed:

* the simple shape has to be found in the same size, same proportions, and the same orientation within the complex figure as when it appeared alone in the third page (the given specimen).
* the pupil is not allowed to use a ruler or any other means to measure the size of the simple shape in the complex figures.
* there is more than one simple shape embedded in some complex figures but the pupil is required to locate only the simple shape which is in the same proportion, size, and orientation as the specimen. If the pupil finds more than one correct answer (one complex figure has more than one correct answer), then he is required to trace only one.
* the test booklet should be collected from the pupils after 20 minutes.

The basic marking scheme which was used for the HFT was to give one mark for each correct complex figure found by the pupil. The over-all sum of these marks is calculated to ascertain the total mark which each pupil gained. The maximum mark that can be obtained is 18 since the test comprises of 18 complex figures. The HFT scoring key is to be found in the appendix 2.

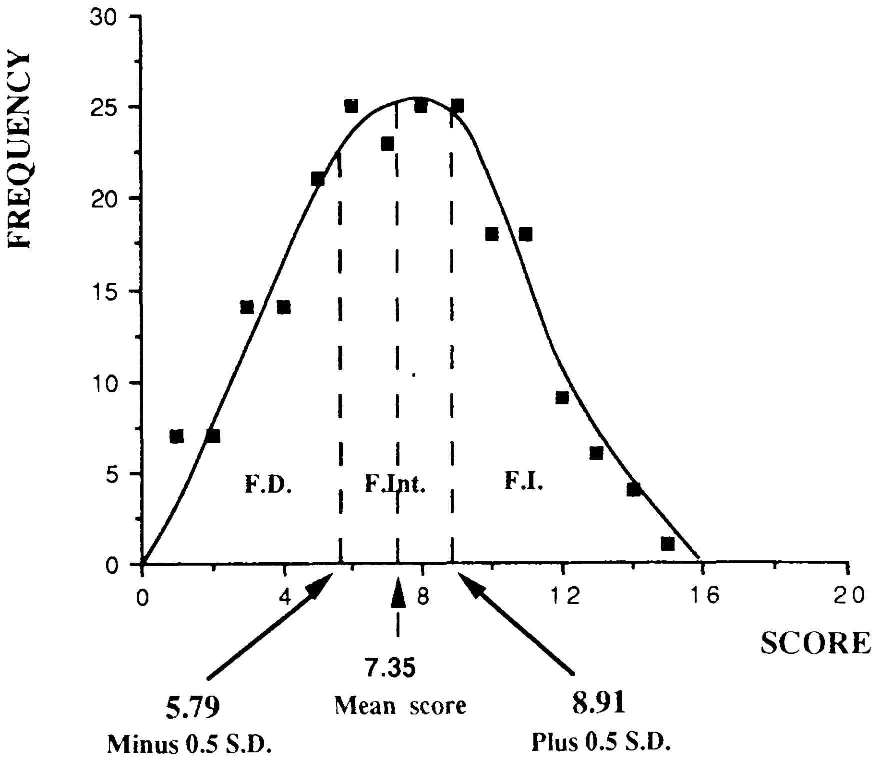
4.3.3 The Application of HFT to the Sample

Pupils who attempted the HFT were divided into three categories according to their scores; field-dependent; field-intermediate; and field-independent pupils. Such a classification of pupils is shown in table 4.2. The distribution of the HFT total scores for the sample is exhibited in figure 4.1. The criterion used for such division is based upon the method which was employed by Case[7], Scardamalia[9], and Case and Globerson[42].

Table 4.2

Classification of the sample

Group	No. of pupils
F.D.	63
F.Int.	73
F.I.	81
Total	217



S.D. Standard Deviation

Figure 4.1 The distribution of HFT total scores for the sample.

The simple application of the criterion is to consider pupils who scored more than half a standard deviation above the mean score as field-independent, while pupils who scored less than half a standard deviation below the mean score were considered as field-dependent. The pupils who scored in between $\pm$ 0.5 standard deviation were considered as field-intermediate (although this research is not essentially concerned with this intermediate category of pupils).

4.4 Tests for the Assignment of Convergent/Divergent Thinking Styles

Having measured the degree of field-dependence/field-independence of the sample, the focus of the research shifts to the assignment of pupils' convergent and divergent thinking styles.

The main purpose of such an assignment is to classify pupils into those who have the ability to be more divergent thinkers rather than convergent thinkers as divergent thinkers would be more likely to give a greater variety of answers to each question. Based upon Hudson's (1966) work[19], Child and Smithers (1973)[48] distinguished convergent thinkers by their high achievement in problems requiring one conventionally accepted solution which is obtainable from the given information (as in intelligence tests). Meanwhile, convergent pupils would be more likely to have a more diminished ability than divergent pupils in providing a variety of answers to each question. The convergent thinkers would obtain low scores in problems requiring the generation of several equally acceptable solutions (as in divergent thinking test)

4.4.1 The Description of Tests

This study is based upon Hudson's[19] original work. The researcher designed six mini tests in which each is allowed a limited time for completion. The pupil is required to write as many answers as possible for every question he is given:

I - *Test 1*: This test was designed in order to find out the pupil's ability to think of as many different words as possible having the same or similar meaning to the one which is given. Moreover, an example is provided at the beginning of the test to clarify what the pupil is required to do. The time limit which has been set up for this test is 5 minutes.

II - *Test 2*: The pupil is asked in this test to write as many sentences as possible comprising of four given specific words in each sentence. These given words should be used in any constructive sentence in the same order in which they were written in the test. Again, an example is provided at the beginning of the test, and 5 minutes is set as the time limit for such a test.

III - *Test 3*: Most convergent/divergent tests are verbal, so that the researcher decided to involve at least one pictorial test. It is prudent to mention that verbal tests could prove arduous for some pupils, especially those who have difficulty in language or writing and therefore pictorial tests may be considered as an opportunity for such pupils to express easily their own ideas and imaginations. In test 3, the pupil is required to draw up to five symbols for each word or phrase given. 5 Minutes is set as the time limit for this test, and one example is provided to illustrate the test.

IV - *Test 4*: This test is intended to reflect pupils' thinking ability about subjects. The pupil is asked to write all the things "which are round or which are round more often than any other shape". The time limit is 3 minutes, and the pupil is given an example at the beginning of the test to illustrate what is required of them.

V - *Test 5*: It is similar to test 4 in reflecting pupils thinking ability. The pupil is required to think about various words which begin with the letter G and end with the letter T, names of people or places are not allowed. An example is given for this test, 4 minutes is set as the time limit for the completion.

VI - *Test 6*: It is a free-imagination test. Pupils are given a specific topic and asked to write as many ideas as they can about such a topic without any restrictions. This test may make demands upon the pupils' ability in composition and imagination. An example is provided at the beginning of the test, and 4 minutes is set as the time limit.

The time allocated for the 6 convergent/divergent tests is 25 minutes. One mark is given[19] for every single correct response, and the highest possible score that could be gathered in these tests is 130. A copy of the convergent/divergent tests is shown in appendix 3. Moreover, some selected interesting responses from pupils in such tests are to be displayed in the appendix 4.

4.4.2 The Division of the Sample into Convergers and Divergers

The present study is not intended to draw different categories among its sample concerning convergent and divergent thinking styles, as this may be found in Hudson's (1966)[19] work.

Instead, pupils will be considered as high achievers (more likely to be divergers) or as low achievers (more likely to be convergers) regarding their scores in the convergent/divergent tests. Table 4.3 shows the pupils' scores in such tests with their classification into convergers and divergers. Also, the distribution of the convergent/divergent tests total scores for the sample is shown in figure 4.2.

The mean score (49.9) will be regarded as a crucial point between moving from convergent thinking into divergent thinking styles or visa versa. Therefore, moving up from the mean score along with the direction of the upper arrow (number of pupils involved = 111) would represent pupils of higher convergent thinking style rather than divergent thinking style, while in moving down from the mean score along with the lower arrow (number of pupils involved = 106) would represent pupils of stronger divergent thinking style rather than convergent thinking style.

The same idea is to be found in figure 4.2. Moving left along with the left arrow means the subjects are more convergent while moving right along with the right arrow means the subjects are more divergent in thinking styles.

Table 4.3

Pupils scores and classification in the convergent/divergent test

Scores	Frequency	Classification
0 ⟷ 9	0	Convergent thinking
10 ⟷ 19	2	↑
20 ⟷ 29	9	No. of pupils involved = 111
30 ⟷ 39	43	
40 ⟷ 49	57	
		Mean score = 49.9
50 ⟷ 59	56	
60 ⟷ 69	33	No. of pupils involved = 106
70 ⟷ 79	13	
80 ⟷ 89	3	↓
90 ⟷ 99	0	
100 ⟷ 109	1	Divergent thinking
110 ⟷ 119	0	
120 ⟷ 130	0	
Total	217	217

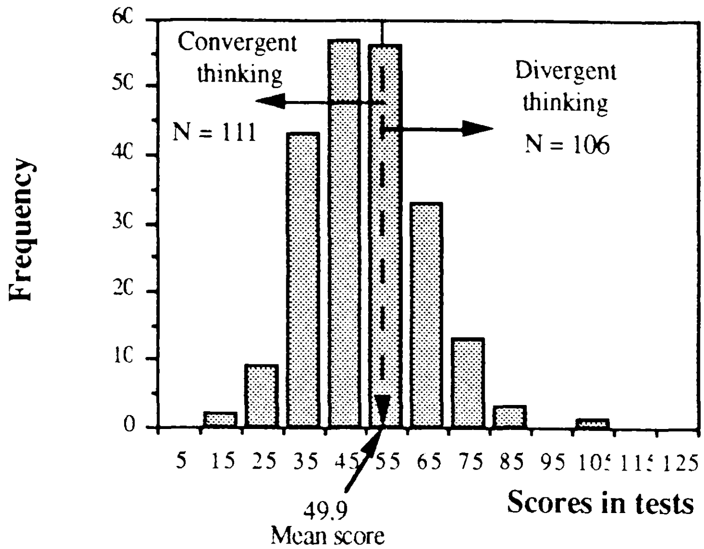


Figure 4.2 The distribution of the convergent/divergent tests total scores for the sample.

4.5 The Measurement of the Sample Motivational Characteristics

The next phase in the present research is to divide the sample of this study into four possible groups regarding pupils' motivational characteristics. Based upon some work which was done by Adar (1969)[21] and by Hofstein and Kempa (1985)[22], the Centre for Science Education at Glasgow University produced a series of tests for measuring the motivation factor.

4.5.1 What is the Nature of the Original Motivation Test?

The original test which was designed for the purpose of measuring the students' motivational traits or preferences can be found in Adar's (1969)[21] work. This test was used again in Martin Diaz's (1990)[86] research. The main method of such a test is to ask students to select a certain number of statements (concern studying at schools) from a huge number of statements displayed (as many as 80) which may best describe the students' feeling. Such statements are intended to indicate a student's motivational preferences or characteristics.

There are four different groups of statements related to the four motivational patterns which have been suggested:

* *the achiever pupil* who has a distinct preference for an expository method of teaching and learning. He enjoys the challenge competing with others for top marks and hates being held back by a teacher who has to deal with slow pupils. The achiever pupil seems apathetic towards any special interaction in learning.
* *the conscientious pupil* who would also displays a distinct preference for an expository method of teaching and learning. But he also wants to know in advance the aims and goals of the work that he will be involved in with precise instructions which will allow him not to make mistakes. He will not participate in any unnecessary activities during exam time.
* *the curious pupil* who may be assumed to have a strong preference for discovery and problem-solving activities. He prefers open-ended learning tasks, likes to fellow his own practical ideas rather than rigid instructions.
* *the social pupil* who seems to be very sociable in all his activities. Even during his studies, he prefers to study with friends and to discuss problems together. He is often too involved with external world to commit himself to consistent studying.

In the original motivation test, every single statement was scored by every pupil on a five point scale giving rise to a set of ordinal numbers. These ordinal numbers were then treated like cardinal numbers and averaged to give a score which allocated each pupil to one of the four categories.

This method, from the above description, is obviously long. The student may easily get bored once he realises the number of statements involved in the test, in addition to the length of time which such a test requires. Another point of criticism of such a method is that the numbers that have been used to agree or disagree with any statement are ordinal numbers which could be defined as labels of some sort of order in a situation in which the intervals are not necessarily evenly spaced and so cannot be used in arithmetical operations. The total score of each student's responses sheet was treated as a cardinal number or as a real number which is capable of all arithmetical operations. For example, a choice of 4 for one statement cannot be twice as valuable as 2 for another statement. Averages become meaningless.

4.5.2 The Initial Motivation Test in the Present Study

Being aware of the deficiencies of the original motivation test, attention was given to the invention of a new test which may be more reliable and more practical for age group of children in secondary schools. Therefore, our initial motivation test was designed to have a maximum of 16 statements in boxes. These statements should have a connection with the pupils study at the school. Every four statements were used to define one group of the four motivational groups or patterns (the achiever, conscientious, curious, and social). The pupil was simply asked to select up to *five* statements which he/she thought most appropriately correlated with his/her own feelings about studying. A sample of this test is shown in figure 4.3. Figure 4.4 displays the motivational pattern (group) involved in every single statement in the test. The initial motivation test which was conducted in schools with the distribution of the sample are shown in table 4.4.

UNIVERSITY OF GLASGOW

CENTRE FOR SCIENCE EDUCATION

NAME________________________

Instructions : (1) Please read carefully ALL the statements in the following grid.

(2) Select up to FIVE descriptions which you think MOST CLOSELY fit your own feelings about studying.

(3) Fill the numbers you have selected into the bracket on the right : (   )

1 I enjoy studying with my friends and discussing our problems together.	2 It is very important to me to be in the top few of the class.	3 When exam times come round I out out other activities to concentrate on study.	4 I hate being held back by the teacher having to deal with slow students.
5 The support of my friends is very important to me during exam times.	6 My social and recreational interests are very important to me.	7 I am keen to learn about the latest discoveries and inventions rather than sticking to set materials.	8 I am normally so busy enjoying life that I tend to put off my study till the last minute.
9 In class I enjoy hearing about the applications to everyday life whether they are examined or not.	10 Class discussions are boring if you have to listen to a lot of obviously wrong answers from others.	11 Practicals with very rigid instructions bore me. I prefer to follow my own ideas such as in a project.	12 I like practical work when the instructions are clear and you know just where you are and what is expected.
13 I enjoy the challenge of competing with others for top marks.	14 I may not do brilliantly but I feel a duty to do as well as I can.	15 Exams seldom give me a chance to explore the questions properly and show that I can think for myself.	16 I prefer not to offer suggestions in class discussions unless I am sure I am right.

Figure 4.3 The initial motivation test which was used in the study.

UNIVERSITY OF GLASGOW
CENTRE FOR SCIENCE EDUCATION

NAME________________________

Instructions : (1) Please read carefully ALL the statements in the following grid.

(2) Select up to FIVE descriptions which you think MOST CLOSELY fit your own feelings about studying.

(3) Fill the numbers you have selected into the bracket on the right : (   )

1 Soc. I enjoy studying with my friends and discussing our problems together.	2 Ach. It is very important to me to be in the top few of the class.	3 Consc. When exam times come round I cut out other activities to concentrate on study.	4 Ach. I hate being held back by the teacher having to deal with slow students.
5 Soc. The support of my friends is very important to me during exam times.	6 Soc. My social and recreational interests are very important to me.	7 Cur. I am keen to learn about the latest discoveries and inventions rather than sticking to set materials.	8 Soc. I am normally so busy enjoying life that I tend to put off my study till the last minute.
9 Cur. In class I enjoy hearing about the applications to everyday life whether they are examined or not.	10 Ach. Class discussions are boring if you have to listen to a lot of obviously wrong answers from others.	11 Cur. Practicals with very rigid instructions bore me. I prefer to follow my own ideas such as in a project.	12 Consc. I like practical work when the instructions are clear and you know just where you are and what is expected.
13 Ach. I enjoy the challenge of competing with others for top marks.	14 Consc. I may not do brilliantly but I feel a duty to do as well as I can.	15 Cur. Exams seldom give me a chance to explore the questions properly and show that I can think for myself.	16 Consc. I prefer not to offer suggestions in class discussions unless I am sure I am right.

Figure 4.4 The motivational patterns in the initial motivation test.

Table 4.4

The distribution of the sample over the initial motivation test

Motivational patterns	Number of pupils
The achiever	9
The conscientious	68
The curious	12
The social	36
No pattern *	78
No attendance	14
Total	217

* Pupils who are categorised as not belonging to any particular motivational pattern (2:2:1).

The marking scheme which was used in this test is as the following:

I - The pupil would be described as an achiever if he selected three statements or more which represent achiever characteristics.That is if he selected; (i) <u>four</u> achiever statements plus a statement from another pattern (4:1) or (ii) <u>three</u> achiever statements plus two other statements which represent one or two patterns (3:2 or 3:1:1) or (iii) <u>two</u> achiever statements plus one statement from <u>each</u> of the remaining three patterns. The pupil would be described as a conscientious, curious, or social if he selected statements which concerned such motivational patterns by the same way as in the given example (the achiever example).

II - If the pupil selected two statements which reflect, for example, achiever characteristics and two other statements which reflect conscientious characteristics and a statement which reflects curious characteristics (2:2:1), such a pupil will be described not belonging to any particular pattern of motivation (will not be categorised).

III - The pupils who are categorised (2:2:1) as not belonging to any particular motivational pattern (not a clear one) will be treated as holding more than one *obvious* motivational pattern which have been overlapped between them.

IV - Having described any pupil in the sample as an achiever, for example, (from what he/she selected of statements) does <u>not</u> mean that such a pupil has only one achiever motivational trait, but could have another overlapped trait which was less dominant. It is quite possible that the restriction of the test did not allow the pupil to express his feelings fully.

From the analysis of the results, a problem was recognised in designing such a test. Some statements were found to be more appealing to the pupil and may thus have been selected more often than others. In addition, all statements in the test may represent different types of activity, such as the classroom, laboratory, social life, and innovation, which have been drawn together randomly. The researcher believes that such random distribution of the statements may have confused pupils and thus prevented the participant from selecting those most appropriate and suitable.

4.5.3 <u>The Second Motivation Test</u>

Being aware of some deficiencies regarding the first test of motivation as stated in the previous section, the researcher intended to modify the test into a fresh and stimulating format which may have a better chance of representing pupils' motivational patterns:

I - The first attempt which was made concerning such modifications was to examine the 16 statements used in the test. Throughout a similar test administered on a selection of pupils in another school, it was found that some statements have been indeed selected more often than others which might suggest that such statements must be modified. Therefore, a certain number of statements were changed or modified hoping to present statements of equal importance or strength for the pupils.

II - The second attempt was to insert some pictures and pictorial characters in the test in order to give it a more interesting appearance. The 16 displayed statements were drawn in the test as if narrated by different characters (males and females). The pupil is required to identify which character most closely approximates to his/her feelings in what the character says in the statement.

III - Another important change was inserted into the shape of the motivation test. The statements of the test represented different types of activity. The 16 statements therefore were divided into four different categories of activity; (i) about class work (ii) about laboratory (iii) about discovery learning (iv) and about social life. Four different statements (four different motivational patterns) concerning each category were used in each horizontal row (four horizontal rows according to the four different categories of activity).

IV - Three differently coloured versions of the motivation test were produced. The same choices were offered but were scattered differently in each version. This had two purposes (i) to check that the position of each statement was immaterial and (ii) to prevent copying between neighbours.

The pupil was simply asked to read the statements in each row (a category of activity) and to give the name of the character who has an opinion most like the pupil's own. A sample of this test is shown in figure 4.5. The marking scheme which has been used in the test is as follows:

I - The pupil was regarded as, for example, an achiever if he/she described himself/herself as an achiever in the <u>four</u> different categories (four rows) of activity (4:0).

II - The pupil was still regarded as an achiever if he/she described himself/herself as, for example, an achiever in <u>three</u> different categories (three rows) and as a social in the remaining <u>one</u> (3:1).

III - The pupil was regarded as, for example, an achiever if he/she described himself/herself as an achiever in two different categories (<u>two</u> rows) and as a social and a curious in the other two categories (<u>two</u> rows) in the test (2:1:1).

IV - The pupil was regarded as not belonging to any motivational pattern if he/she described himself/herself as, for example, an achiever in two different categories and as a curious in the other two remaining categories (2:2).

V - The pupil was regarded as not belonging to any motivational pattern if he/she described himself/herself as, for example, an achiever in a category, a curious in an another one, a conscientious in the third one, and as a social in the remaining category (1:1:1:1).

Table 4.5 shows the distribution of the sample over the modified motivation test. The number of pupils who did not attend this test is due to the nonparticipation of one school in the test.

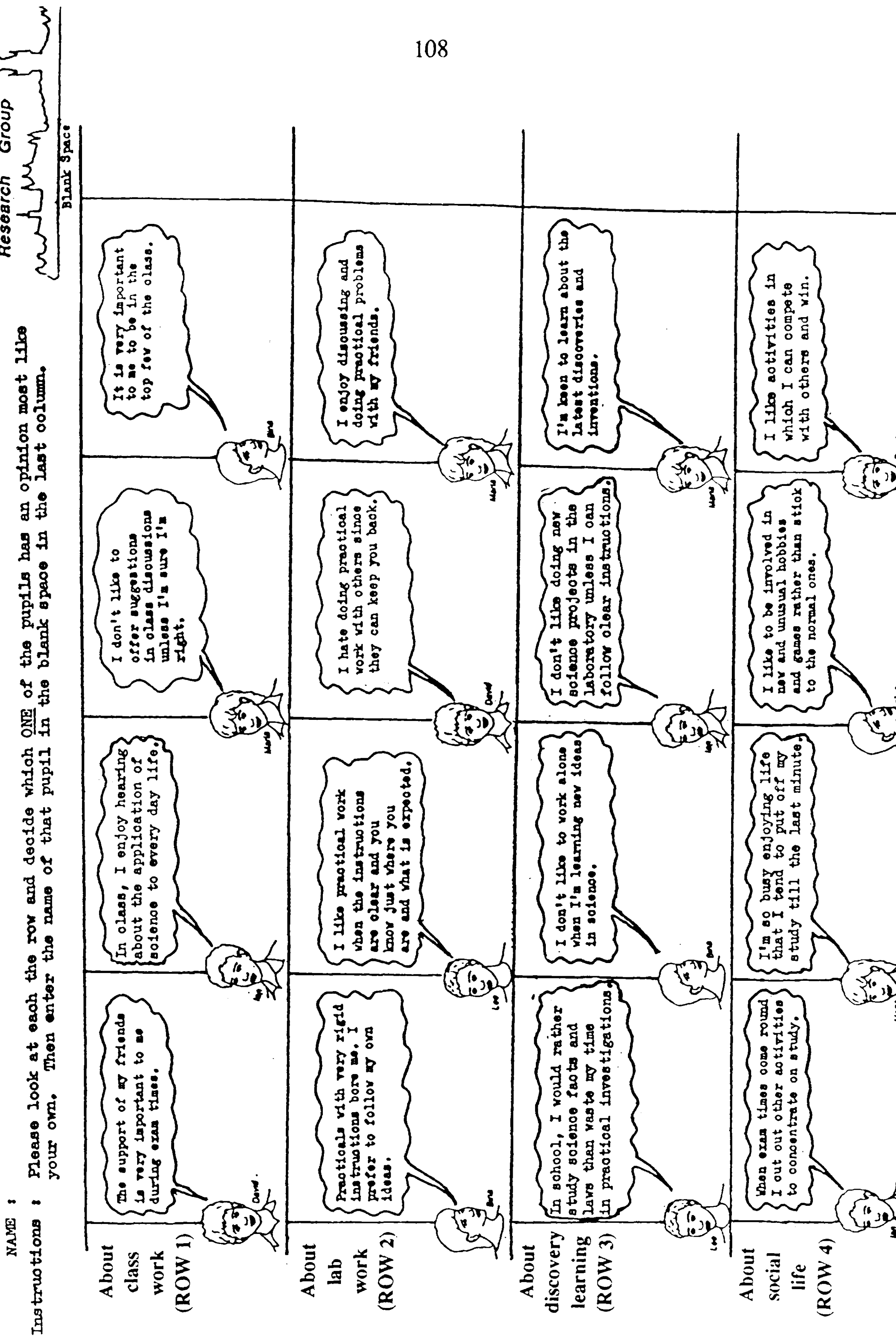


Figure 4.5 The second motivation test (modified version) used in the study.

The modified version of the motivation test has been more successful trial than the initial test in separating the pupils' motivational patterns with less overlapping between patterns for any

individual pupil. However, a question arose concerning what a pupil would choose (to describe himself/herself) if he/she were provided with only the four different pictures of the achiever, conscientious, curious, and social as four distinct clusters.

Therefore, it was worth trying to make another modification to the second version of the motivation test in order to obtain a sharp picture of each pupil's motivational pattern as well as to increase the reliability of the motivation test in measuring such patterns.

Table 4.5

The distribution of the sample over the scored motivation test

Motivational patterns	Number of pupils
The achiever	8
The conscientious	45
The curious	34
The social	47
No pattern *	21
No attendance	62
Total	217

* Pupils who are categorised as not belonging to any particular motivational pattern (2:2 or 1:1:1:1). This category has now dropped from 78/217 to 21/217.

4.5.4 The Final Motivation Test

The final motivation test comprises of two different sheets:

I - The first sheet (A) shows of four different characters (two males and two females), each one has been drawn describing himself/herself in four different statements concerning four different activities (about class work, about laboratory work, about discovery learning, and about social life).The pupil is simply asked to select a single character that he/she may agree with most. The pupil then has to put a tick in the box against any character selected. The hope of this test is that the pupil will select the most likely unique motivational pattern which may describe him/her best without any overlapping with other patterns.

II - However, the second sheet (B) is of another motivation test similar to the second one but with again some modification in the shape of the test and in the statements involved. The pupil is asked to select a character which may describe him/her best in each row.

A copy of the third test is shown in figure 4.6 (sheet A and B). Table 4.6, 4.7 show the distribution of the sample over this test. The marking scheme which was followed in the third motivation test was; (i) by giving the pupil, for the first sheet in the test, a motivational pattern selected in accordance with the involved character, (ii) while, in the second sheet of the test, the same marking scheme which was used in the second motivation test was applied in order to identify the pupils' patterns.

Ultimately, the whole battery of motivation tests were drawn together in order to compare the results. The final motivational traits of pupils which have emerged and the whole picture of tests are shown in table 4.8. Pupils who could not exhibit a significant trend towards a motivational pattern are believed to have two obvious overlapped patterns (at least) and therefore will be treated as not belonging to any motivational pattern.

Glasgow University Science Education Research Group

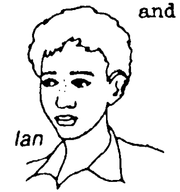
NAME :

Instructions : These four pupils are talking about their science work in school. Which one of these pupils is saying the kind of things with which you agree most. Put a tick (in the box) against the pupil you agree most.

1. In class, I enjoy hearing about the applications of science to everyday life.
2. Practicals with very rigid instructions bore me. I prefer to follow my own ideas.
3. I'm keen to learn about the latest discoveries and inventions.
4. I like to be involved in new and unusual hobbies and games rather than stick to the normal ones.

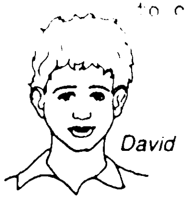
☐

1. It is very important to me to be in the top few of the class.
2. I hate doing practical work with others since they can keep you back.
3. In school, I would rather study science facts and laws than waste my time in practical investigations.
4. I like activities in which I can compete with others and win.



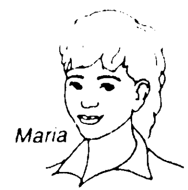
☐

1. I don't like to offer suggestions in class discussions unless I'm sure I'm right.
2. I like practical work when the instructions are clear and you know just where you are and what is expected.
3. I don't like doing new science projects in the lab unless I can follow clear instructions.
4. When exam times come round I cut out other activities to concentrate on study.



☐

1. The support of my friends is very important to me during exam times.
2. I enjoy discussing and doing practical problems with my friends.
3. I don't like to work alone when I'm learning new ideas in science.
4. I'm so busy enjoying life that I tend to put off my study till the last minute.



☐

Figure 4.6 (Sheet A) The third motivation test used in the study.

Glasgow University
Science Education
Research Group

NAME :

Instructions : Please look at each the row of pictures and decide which ONE of the pupils has an opinion most like your own. Then enter the name of that pupil in the blank space in the last column.

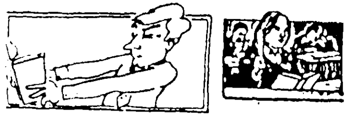
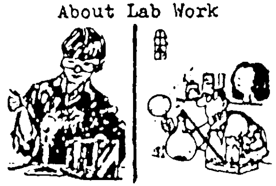
					Blank Space
About Class Work 	In class, I enjoy hearing about the applications to everyday life whether they are examined or not.	The support of my friends is very important to me during exam times.	It is very important to me to be in the top few of the class.	I don't like to offer suggestions in class discussions unless I'm sure I'm right.	
About Lab Work 	I like practical work when the instructions are clear and you know just where you are and what is expected.	I enjoy discussing and doing practical problems with my friends.	Practicals with very rigid instructions bore me. I prefer to follow my own ideas such as in a project.	I hate doing practical work with others since they can keep you back.	
About Discovery Learning 	I don't like planning and investigating new science projects unless I can follow clear instructions.	I'm keen to learn about the latest discoveries and inventions rather than sticking to set materials.	In school, I would rather study science facts and laws than waste my time in planning and carrying out investigations.	I don't like to work alone when I'm learning new ideas in science.	
About Social Life 	I'm normally so busy enjoying life that I tend to put off my study till the last minute	I like social activities in which I can compete with others and win.	When exam times come round I cut out other activities to concentrate on study.	I like to be involved in new and unusual hobbies and games rather than stick to the normal ones.	

Figure 4.6 (Sheet B) The third motivation test used in the study.

Table 4.6

The distribution of the sample over the third motivation test (sheet A)

Motivational patterns	Number of pupils
The achiever	7
The conscientious	57
The curious	34
The social	61
No attendance	58
Total	217

Table 4.7

The distribution of the sample over the third motivation test (sheet B)

Motivational patterns	Number of pupils
The achiever	5
The conscientious	41
The curious	28
The social	46
No pattern *	39
No attendance	58
Total	217

* Pupils who are categorised as not belonging to any particular motivational pattern (2:2 or 1:1:1:1).

Table 4.8

The distribution of the sample over the whole motivation tests

Motivational patterns	Test -1-	Test -2-	Test -3- Sheet A	Test -3- Sheet B	Match
The Achiever	9	8	7	5	11
The Conscientious	68	45	57	41	78
The Curious	12	34	34	28	32
The Social	36	47	61	46	57
No Pattern	78	21	--	39	35 *
No Attendance	14	62	58	56	4 **
Total	217	217	217	217	217

* Pupils who are categorised as not belonging to any particular motivational pattern (as they have two obvious overlapped patterns).

** Pupils who failed to attend any motivation test.

4.6 Summary

This chapter was intended to show the reader the kinds of methodology which were used in order to measure the psychological factors involved in this study. The analysis of the results from such measurements are due to be processed in the next chapter. Field-Dependence/Field-Independence, Convergence/Divergence, and Motivation are three different factors which seem to have an effect firstly upon each other, and secondly on the performance of pupils in science. The Hidden Figure Test, Convergent/Divergent Test, and three types of Motivation Tests, were used successively in order to measure such factors. It is worth mentioning here that the three motivation tests will be incorporated to produce a single pattern which may best describe the pupil according to the motivational traits. The results obtained from this chapter and the analysis of results from the next chapter will be used together later on to correlate with the performance and achievement of pupils in mini-projects in chemistry.

CHAPTER FIVE

POSSIBLE CORRELATIONS BETWEEN PSYCHOLOGICAL FACTORS USED IN THE PRESENT STUDY

5.1 Introduction

The present chapter deals with various statistical correlations which could possibly be discerned between the various psychological factors employed in this research.

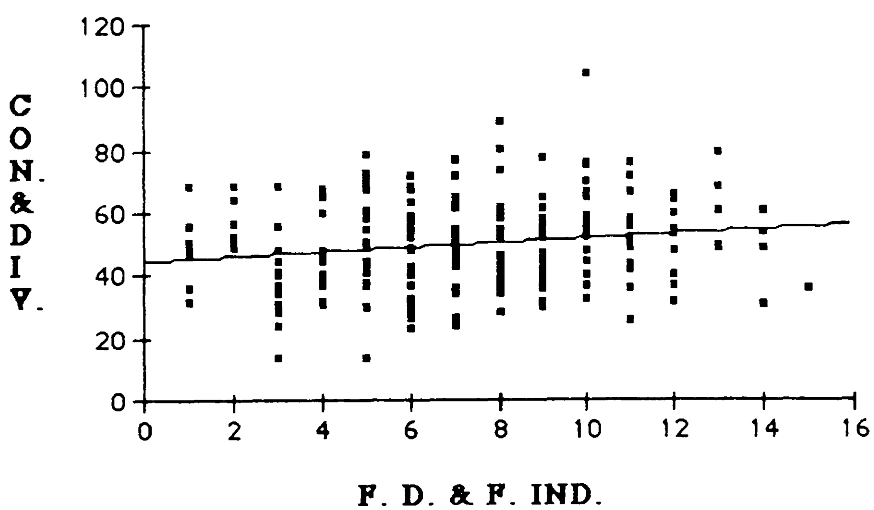
Attention must be drawn to whichever correlations arise from this work and to the possible significance of these correlations. An understanding of the psychological factors involved in this research may lead to an understanding of pupils' achievement or performance in chemistry. Building on this, there may be a significant link between psychology and science learning which could prove to be very profitable. It could lead to improved educational practice.

Field-Dependence/Field-Independence, Convergence/Divergence and Motivation are three psychological factors which are to be explored with the sample of the study in order to find out possible correlations between such factors which may lead to possible predictions for the pupils achievement in practical problem-solving in chemistry. This will be discussed in the next chapters and will rely upon the results which are obtained from this present chapter.

5.2 Possible Correlations between Field-Dependent/Field-Independent Cognitive Styles and Convergent/Divergent Thinking Styles

5.2.1 A Scatter Plot between These Psychological Factors

All the pupils in the sample (217 Pupils) were used in this part of the study as they were full participants in the field-dependent/field-independent and convergent/divergent tests. The results of their achievements in such tests were plotted against each other using a scatter diagram. A significant correlation emerged as the Pearson Product-Moment Correlation Coefficient was 0.1613. The null hypothesis[153, 154] could be rejected at a 5% level. The scatter plot obtained is shown in figure 5.1.



Pearson Correlation = 0.1613 Degrees of freedom = 215 Tail probability = 0.0083

Significant at a 5% level

Figure 5.1 A scatter plot between the sample's scores in field-dependent/field-independent and convergent/divergent tests.

The conclusion which may be drawn from this is that field-independent pupils performed better in convergent/divergent tests and appeared to be more divergent thinkers rather than convergent thinkers. Whilst field-dependent pupils appeared to be more convergent thinkers rather than divergent thinkers in accordance with their lower performance in convergent/divergent tests.

5.2.2 The Distribution of Field-Dependent/Field-Independent Pupils over the Convergent/Divergent Tests

To study the conclusion obtained (in the last section) between field-dependence/field-independence and convergence/divergence, the distribution of the number of field-dependent/field-independent pupils compared with the number of convergent/divergent pupils (pupils' tests attainments) was required, as it would clarify the pupils' percentages distribution in these tests. Table 5.1 shows such a distribution of percentages.

Table 5.1

The distribution of field-dependent/field-independent pupils over the convergent/divergent tests

Groups	F. D. N = 63	F. IND. N = 81
Con. N = 69	36 52%	33 48%
Div. N = 75	27 36%	48 64%

From the above table, the total number of convergent pupils has been almost divided equally in the field-dependent/field-independent test. Half of the convergers seemed to be field-dependent pupils, while the other half seemed to be field-independent pupils. On the other hand, the divergent pupils have shown a good performance in the field-dependent/field-independent test and therefore the test significantly categorises the divergers as field-independent pupils rather than field-dependent pupils.

Could it be that a diverger who is a field-independent pupil will be more creative than others and will achieve more in the open-ended tasks?

5.2.3 Some Predictive Proposals

According to a predictive model[2] based upon the information processing hypothesis and according to several studies devoted to this area[1, 12, 13, 17] , field-independent learners are more able to achieve well in examinations and are more capable of surviving high demand questions when compared with field-dependent learners (probably due to their higher working memory capacity and higher ability in separating the 'signal' from the 'noise' in any task) . Therefore, if a pupil is field-independent and divergent, it could be expected that he/she will perform well in a science activity and will perform best, especially in creative science tasks (for example, open-ended problem-solving activities); tasks which require an ability to "combine ideas, things, techniques, or approaches in a new way"[56]. Building on this, a field-independent and convergent pupil will probably perform well in conventional science examinations, but that does not necessarily mean that he/she will be able to perform satisfactorily or well in open-ended practical problem-solving (creative tasks) in chemistry.

Although field-dependent pupils may not perform well in the conventional science examinations compared to the field-independent pupils, field-dependent and divergent pupils could still perform better in creative tasks than field-dependent and convergent pupils. It is a predictive proposal which requires investigation (in the next chapters).

From figure 5.1 and table 5.1, field-dependent pupils tended to be more convergent thinkers rather than divergent thinkers. Such findings concerning field-dependent pupils could be suggested as a reason for their achievement especially in conventional science examinations which do not demand creativity. The convergent thinking ability could boost learning in different ways. The convergers' intelligence, as stated in chapter two, consists of a narrowing in focus, an imaginative austerity which can be quite formidable.

5.2.4. Patterns of the Mean Scores in both Psychological Tests

A picture of the mean scores of field-dependent/field-independent pupils in the convergent/divergent tests, and a picture of the mean scores of convergent/divergent pupils in the field-dependent/field-independent test could also be beneficial to the understanding of such groups. Table 5.2 and 5.3 show the groups' mean scores in such tests.

Table 5.2

The mean scores of field-dependent/field-independent pupils in convergent/divergent tests

Groups	F. D. N = 63	F. IND. N = 81
Mean scores in Con. & Div. Tests	47.6	52.6

Table 5.3

Convergers and divergers' mean scores in the field-dependent/field-independent test

Groups	CON. N = 69	DIV. N = 75
Mean scores in F.D.& F.I. Test	**6.9**	**7.8**

The mean scores of field-dependent/field-independent pupils in convergent/divergent tests did not reveal significant differences in achievement between field-dependent than field-independent pupils as shown in table 5.2. If the Hudson's scale[19] was applied, it would locate both groups (F.D./F.IND.) in the all-rounders division.

A similar result was obtained from the mean scores of convergent/divergent pupils in the field-dependent/field-independent test as shown in table 5.3. The mean scores of both groups (CON./DIV.) were intermediates in such a test (F.D./F.IND.), and there is no significance or remarkable differentiation obtained between the mean scores' achievements of the convergent and the divergent thinkers.

5.3 The Interaction between Motivation, Field-Dependence/Field-Independence and Convergence/Divergence in This Research

In this section and the next (5.4), various attempts will be made to find out any fine connections between the psychological dimensions (Motivation, Field-Dependence/Field-Independence and Convergence/Divergence) which have been used in the present study.

Regarding the motivational patterns, it was evident from the previous chapter that there is an overlapped picture between such patterns. A pupil who was categorised as, for example, a curious would probably have another motivational pattern which did not dominate the pupil's answers in the test sheet. Before studying interactions between the psychological factors, it is worth paying attention to such an overlapping picture.

5.3.1 What Overlapping Pictures were Obtained between Motivational Patterns?

Three motivation tests were conducted in this research in order to classify each pupil in the research's sample as belonging to one of the four motivational patterns (the achiever, conscientious, curious, and the social). However, an overlapping picture between such patterns was obtained.

The final scheme which was used in the present study to describe each pupil as belonging to a certain motivational pattern relied on which pattern was most frequently selected by the pupil in the whole battery of motivation tests. It was possible for the participants to select motivational patterns up to 14 times in the three tests.

A pupil will be categorised as an achiever, as stated in chapter four, if he/she selected the achiever pattern more often than any other pattern. But, it could be that; (i) a pupil may select, for example, 7 times the achiever pattern and 7 times the curious pattern (7:7) and therefore could be categorised as having two overlapping motivational patterns, (ii) or a pupil may have an overwhelming and obvious motivational pattern which appears throughout his/her selections (14 times) in the tests, in addition to another pattern which is not quite as formidable (not as overpowering) as the first one, (iii) or a pupil may have three selections (even four sometimes) of motivational patterns, but of which two are more obvious and more often selected than the other(s), and one of the selected two will be more dominant than the other one in accordance with how many times this selection was made.

Apparently, an amount of overlap between motivational patterns was found to be persistent in almost all the sample. It is therefore rational to say that the vast majority of pupils in the sample have more than one motivational pattern and even if they have a single obvious motivational pattern it is still likely to overlap with at least another one.

To study such an overlap between motivational patterns, each pupil's selection was checked individually in all motivation tests to find out the interacting picture (an overlap) between the motivational patterns of the sample. Table 5.4 exhibits the overlapping picture between the motivational patterns of the sample.

Table 5.4

The population of pupils' motivational groups (patterns) as overlapped with other motivational patterns

Motivational Patterns					Pupils' Groups N=178*
No ** Pattern	Social	Curious	Conscien.	Achiever	
3	3	1	4	0	Achiev. N = 11
14	43	14	0	7	Conscie. N = 78
7	13	0	8	4	Curious N = 32
8	0	9	38	2	Social N = 57

* Total number of pupils who were categorised as belonging to certain motivational patterns. 39 Pupils of the total number of the sample (N = 217) were ignored either because they did not attend any motivation test (N = 4) or did not clearly belonging to any motivational pattern (N = 35).

** Pupils who showed an overlap between more than two motivational patterns and were therefore ignored from the interacting patterns procedure.

To show the size of the overlapping areas between motivational patterns, a study of each motivational group of pupils was necessary. In any motivational group, the biggest overlapping area with other motivational patterns will be designated depending upon the highest frequency number of pupils of such a group (any group such as the achiever or the curious) who would overlap with other motivational patterns. To facilitate such a picture of the overlap for each pupils' motivational group, figure 5.2, 5.3, 5.4, 5.5 display the frequency number of pupils in each group which overlapped with other motivational patterns.

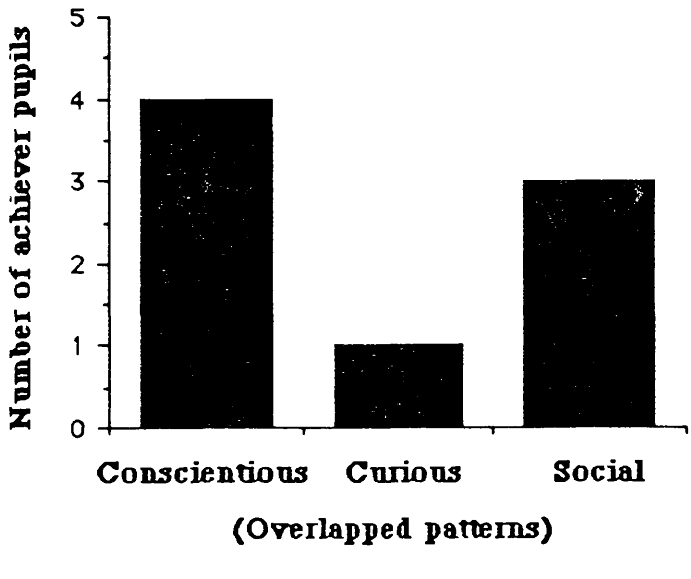


Figure 5.2 The *achiever* pupils (N = 11) as overlapped with other motivational patterns in the motivation tests.

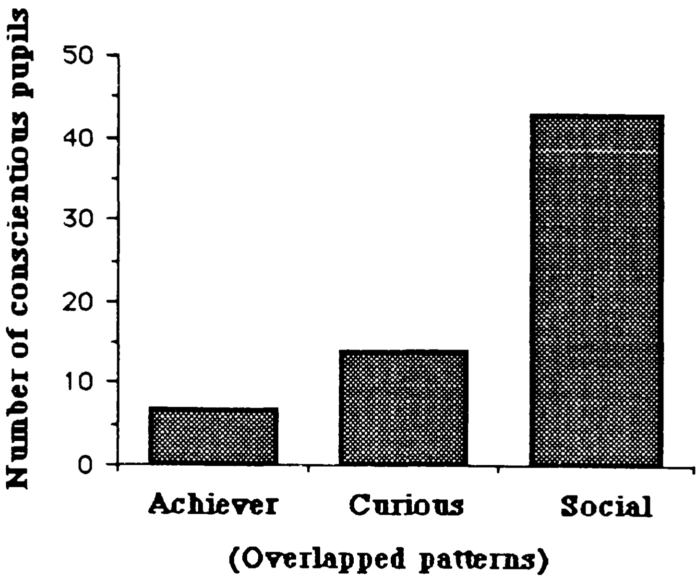


Figure 5.3 The *conscientious* pupils (N = 78) as overlapped with other motivational patterns in the motivation tests.

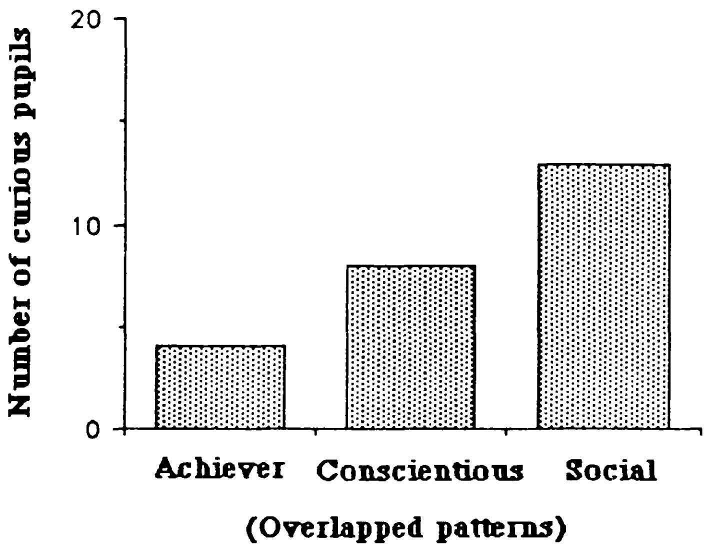


Figure 5.4 The *curious* pupils (N = 32) as overlapped with other motivational patterns in the motivation tests.

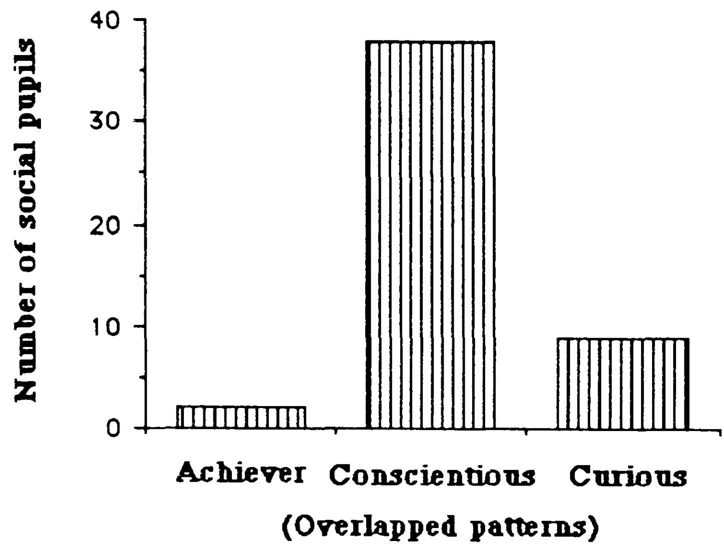


Figure 5.5 The *social* pupils (N = 57) as overlapped with other motivational patterns in the motivation tests.

From table 5.4, it is evident that there are some motivational patterns which have more often overlapped with others, and table 5.5 highlights these overlapped motivational patterns. The conscientious and the social patterns constituted in the first place the highest overlapping picture obtained between motivational patterns. In the second place, the social pattern formed an overlapping picture with the curious pattern, as did the conscientious pattern with the curious pattern.

In general, pupils who were classified as conscientious were found to have more often a social motivational pattern which overlapped with their dominant conscientious pattern. The same pattern might be expected for the social pupils who would have more often overlapped with conscientious pattern in addition to their dominant social pattern. Therefore, these patterns could influence each other positively and though the pupil who shows a preference for formal modes of teaching (with precise instructions) and who shows a need to study and learn as duties (conscientious features) would be expected to show a need to affiliate and to learn in a non-competitive environment (social features) too.

Table 5.5

The population of pupils' motivational groups (patterns) as overlapped with other motivational patterns with highlights the overlapping pictures

Motivational Patterns					Pupils' Groups N=178
No Pattern	Social	Curious	Conscien.	Achiever	
3	3	1	4	0	Achiev. N = 11
14	43	14	0	7	Conscie. N = 78
7	13	0	8	4	Curious N = 32
8	0	9	38	2	Social N = 57

An overlap between the social and conscientious patterns.

An overlap between the social and curious patterns.

An overlap between the conscientious and curious patterns.

On the other hand, the overlapping pictures between the curious-social patterns and the curious-conscientious patterns would mean overlapping features between the curious pattern and social-conscientious patterns. A curious pupil will therefore be expected to have another motivational pattern, and if so will be more likely to have a conscientious pattern or a social pattern. Additionally, a social pupil may have a curious pattern (it is not as likely as having a conscientious pattern) and a conscientious pupil may have a curious pattern (it is not as likely as having a social pattern).

5.3.2 Field-Dependence/Field-Independence Compared with the Motivation Tests

An attempt was made to find out how field-dependent/field-independent pupils of the present study were distributed in the motivation tests (table 5.6).

Table 5.6

The distribution of field-dependent/field-independent pupils over the motivation tests

Groups	Ach.	Consc.	Cur.	Soc.	No * pattern
F. D. N = 63	1 2%	33 52%	6 10%	16 25%	7 11%
F. IND. N = 81	3 4%	24 30%	13 16%	27 33%	14 17%

* Comprises of pupils who have more than one motivational pattern (overlapped), and pupils who did not attend motivation tests.

It is possible to notice from such a distribution that field-independent pupils are more likely to have an achiever or curious or social motivational preference rather than a conscientious preference when compared with field-dependent pupils. Of course, some pupils of both field-dependent/field-independent groups will have an overlapped motivational pattern.

To conclude, the conscientious pupils seem likely to be field-dependent, who do not take the risk of doing, for example, unnecessary practical or theoretical activities particularly without following clear instructions. This may be related to a modest working memory capacity(13) hampered by an inability to separate the 'signal' from the 'noise' efficiently like field-independent pupils. On the other hand, some field-independent pupils may have an achiever motivation due to their sizable working memory capacity which could be used efficiently because they can separate between the 'signal' from the 'noise'. This efficient use of working memory may allow them to do tasks or be eager to do tasks without following clear instructions (a feature of the curious) or may even help them in communicating with other pupils (a feature of the social). The number of field-independent pupils who are at the same time curious or social may be an indication of what has been explained comparing to the number of field-dependent pupils.

5.3.3 Convergence/Divergence Comparisons with the Motivation Tests

The picture which was obtained from distributing the convergent/divergent pupils over their motivational preferences designated in the motivation tests is shown in table 5.7. The divergent thinking pupils seem to distribute themselves over the motivation tests in a way which is similar to field-independent pupils in the previous section. The conscientious preference was seen as more likely to be held by the convergent pupils rather than by the divergent pupils. For the other three preferences (the achiever, curious and social preferences), table 5.7 shows that the divergent thinking pupils seem to select these rather than the convergent thinking pupils.

It could be that the convergent pupil is one who is not attracted to learning by doing activities which have been set up without clear instructions. While the divergent pupil is a pupil who is more adventurous in learning, he likes activities which involve new discovery and exploration and doing tasks without recipe-following instructions.

No significant correlation could be obtained in table 5.7 between the numbers of convergent and divergent pupils over the motivation tests. However, the divergent pupils have exhibited a preference (high number of pupils) for being achievers or curious or social more likely than being conscientious when compared with the number of their convergent colleagues who exhibited low numbers in all the motivational groups apart of the conscientious group.

Table 5.7

The distribution of field-dependent/field-independent pupils over the motivation tests

Groups	Ach.	Consc.	Cur.	Soc.	No * pattern
CON. N = 111	3 3%	45 41%	13 12%	24 22%	26 23%
DIV. N = 106	8 8%	32 30%	19 18%	33 31%	14 13%

* Comprises of pupils who have more than one motivational pattern (overlapped), and pupils who did not attend motivation tests.

From such findings, it seems now prudent to look statistically at the three psychological factors together in order to draw a precise picture for what might be expected in the chemistry performance which will be discussed in chapter 6 and 7.

5.4 <u>The Overall Picture Obtained between the Three Factors Together (Motivation, Field-Dependence/Field-Independence and Convergence/Divergence).</u>

Having discussed the correlation between every two psychological factors involved in the research. Now it is beneficial to study the three different factors together and to find out correlations that could be gathered from such a combination.

An attempt was made to study the pupils' motivational preferences separately in comparison with their achievements in the other two psychological factors involved in this research. Table 5.8 shows the whole picture of pupils (numbers and percentages) in the motivational groups with their attainment and classification in the field-dependent/field-independent and convergent/divergent tests.

Table 5.8

The distribution of the sample over the three psychological factors

Pupils' groups	Achiever	Conscien.	Curious	Social
Field-Dependent N = 63	1 2%	33 52%	6 10%	16 25%
Field-Independent N = 81	3 4%	24 30%	13 16%	27 33%
Covergent N = 111	3 3%	45 41%	13 12%	24 22%
Divergent N = 106	8 8%	32 30%	19 18%	33 31%

In fact, table 5.8 is a combination of table 5.6 and 5.7 which was drawn to display a complete picture for the reader about the distribution of the sample. It is apparent from table 5.8 and from the distribution and number of pupils in all the psychological tests that the achiever, curious and social pupils, on one extreme, tend to be field-independent and divergent pupils. The conscientious pupils, on the other extreme, tend to be field-dependent and convergent pupils. Table 5.9 highlights the highest distribution of motivational groups of the sample in the involved psychological tests.

Table 5.9

The higher distribution of motivational groups of the sample in F.D./F.IND. and CON./DIV. tests

Pupils' groups	Achiever	Conscien.	Curious	Social
Field-Dependent N = 63	1 2%	33 52%	6 10%	16 25%
Field-Independent N = 81	3 4%	24 30%	13 16%	27 33%
Covergent N = 111	3 3%	45 41%	13 12%	24 22%
Divergent N = 106	8 8%	32 30%	19 18%	33 31%

The motivational groups in their highest distribution number in the field-dependent/field-independent test.

The motivational groups in their highest distribution number in the convergent/divergent tests.

Although such findings did not lend themselves to very significant statistical correlations, the general trend of the pupils in their motivational groups did indicate that some correlations like the ones mentioned existed. In general, pupils who are field-independent and divergent are more likely than others to dominate their school classes in discussion, competing with others for the highest score (achiever), discovery learning (curious), learning without guidance (curious), and being friendly with others (social). This category of pupils, as stated earlier, may have a sizable working memory capacity and therefore may be capable of using such a capacity in an efficient way allowing them to solve their problems better than others. Some field-independent and divergent pupils may approach the solution to a problem in a brilliant way, they could probably show sometimes a new technique or skill (creativity) in solving such a problem than other pupils (the curious pupils are recognised to be among this group of pupils).

On the other hand, field-dependent and convergent pupils could be less capable in manufacturing new techniques or skills in solving problems. Moreover, they would be expected to be hesitant in engaging in activities which require a creative ability like open-ended problem solving, they restrict themselves to the received instructions from the teacher in classroom learning, as in doing any other practical activity. It seems that such pupils have not a very large working memory capacity which could be the reason for their restriction to their teachers's instructions and their concomitant unease of being involved in activities which require a sort of creative ability in thinking and progressing. In addition, this could be a reason for the fact that this group is more likely to be convergent thinkers rather than divergent thinkers. The conscientious pupils are seen to be the typical example of this group (field-dependent and convergent group) as these pupils have more often distributed themselves across such a group than other pupils.

Another way of looking at the data may be obtained from the psychology involved in this research in that one may pursue each psychological group individually in terms of what such groups attained in other psychological tests. This method could highlight the biggest clusters of pupils gathered in psychological groups, it could be that such clusters may help in the prediction of the pupils' future achievement in science as will be elaborated upon in chapter seven.

The first group to be placed beneath the microscope is the field-dependent group. This group did not show a significant trend towards one of the convergent/divergent thinking styles, however, it showed a slight trend towards being convergent rather than divergent. It also showed a noticeable preference for being conscientious rather than any other motivational pattern in motivation tests. Therefore, this may again confirm that field-dependent pupils are pretty convergent in thinking and are more likely conscientious in motivation. Figure 5.6 shows how field-dependent pupils were pursued in the psychology involved in this research.

Hypothesis (1): <u>The divergent thinkers pupils of this group may be expected to achieve better at practical problem solving in chemistry such as the mini-projects compared to the convergent thinkers of the same group.</u>

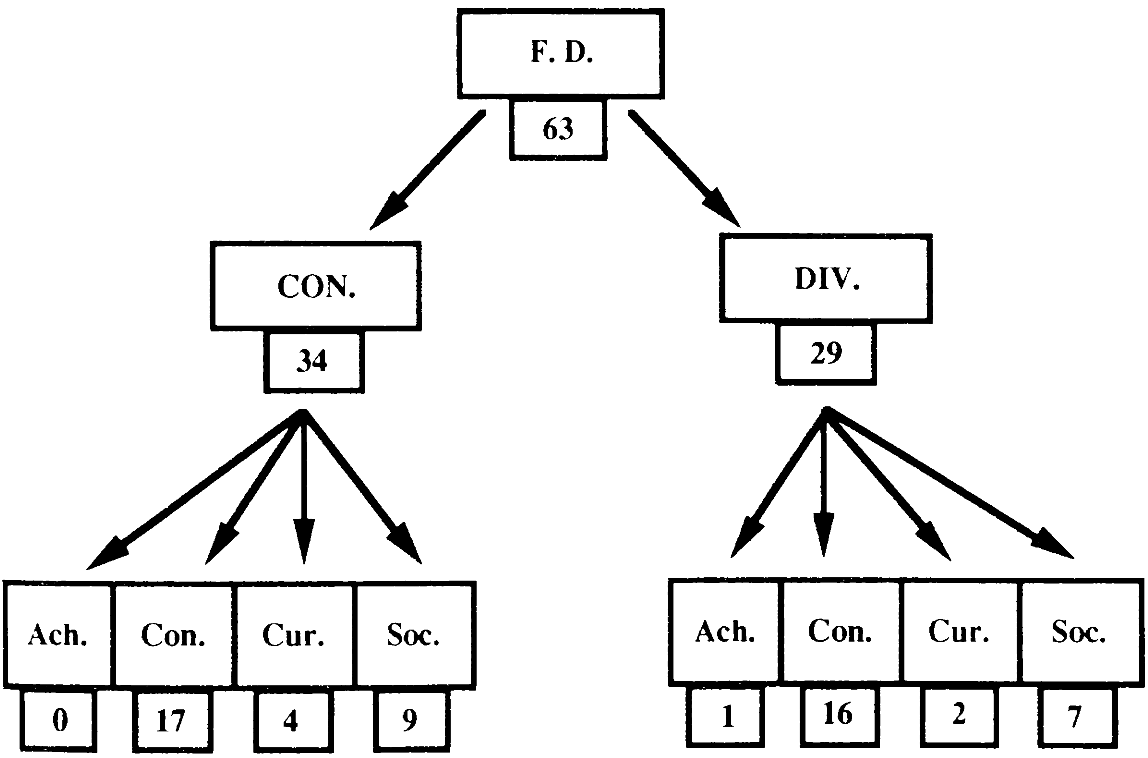


Figure 5.6 Field-dependent pupils as followed in the involved psychology of this study.

Field-independent pupils (figure 5.7), as the second group which will be considered, showed a general trend towards being divergent rather than convergent thinkers. Such a trend, however, is not very strong (about 60% of field-independent pupils), but it could be an indication that field-independent pupils are more likely to be divergent thinkers (as was mentioned earlier).

In motivation groups, field-independent divergent pupils were shown as divided almost evenly between all the groups apart from the achiever group (because of the small total number of the achiever group in the whole sample). A significant number of these pupils were shown as belonging to the curious group (so as to the achiever group) in motivation comparing to the field-independent convergent pupils.

Hypothesis (2): The curious and the achiever pupils of such a group could be expected to show a good achievement and performance in practical problem solving in chemistry.

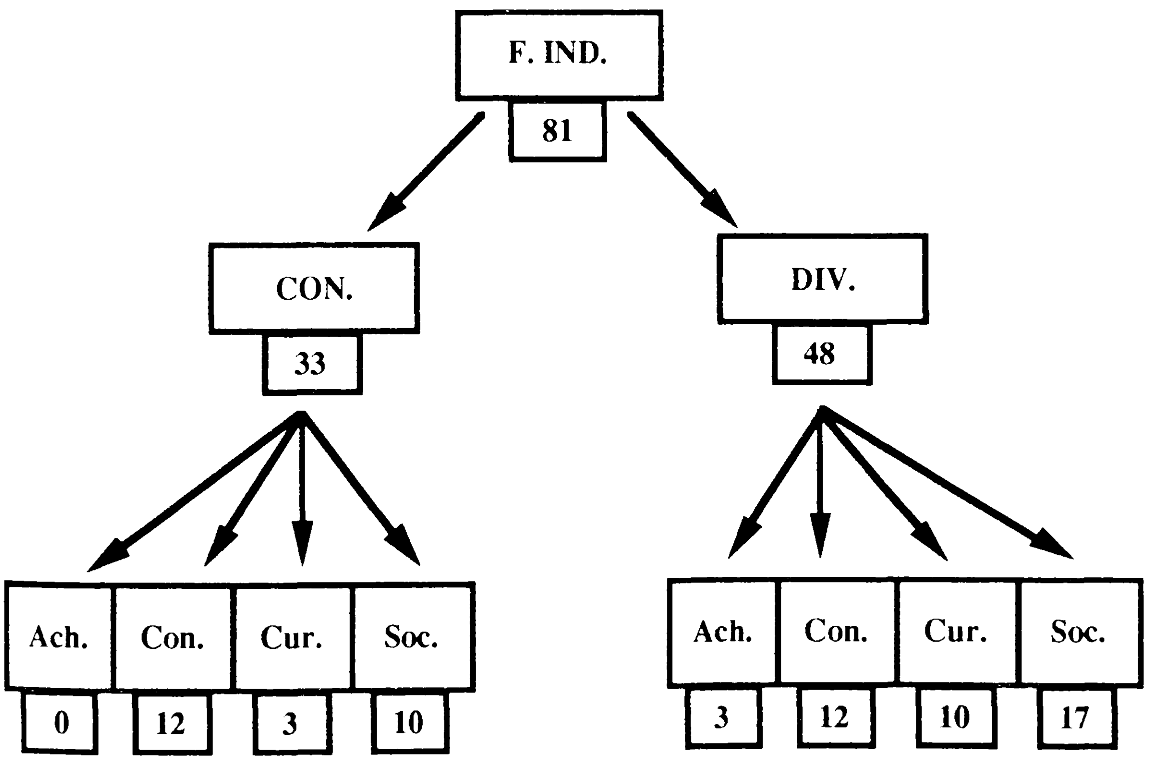


Figure 5.7 Field-independent pupils as followed in the involved psychology of this study.

From figure 5.7, the highest distribution of field-independent convergent pupils were shown as being conscientious and social in motivation more often than belonging to any other motivational patterns.

Hypothesis (3): The field-independent convergent thinkers could be expected to display a poorer performance and achievement in practical problem-solving in chemistry compared to the field-independent divergent thinkers.

Moving to the convergent/divergent angles, the convergent pupils in the pursuit grid showed a similar distribution in the number of pupils being field-dependent or field-independent. Figure 5.8 shows the distribution of convergent thinkers in the rest of the psychological tests which were used in this study.

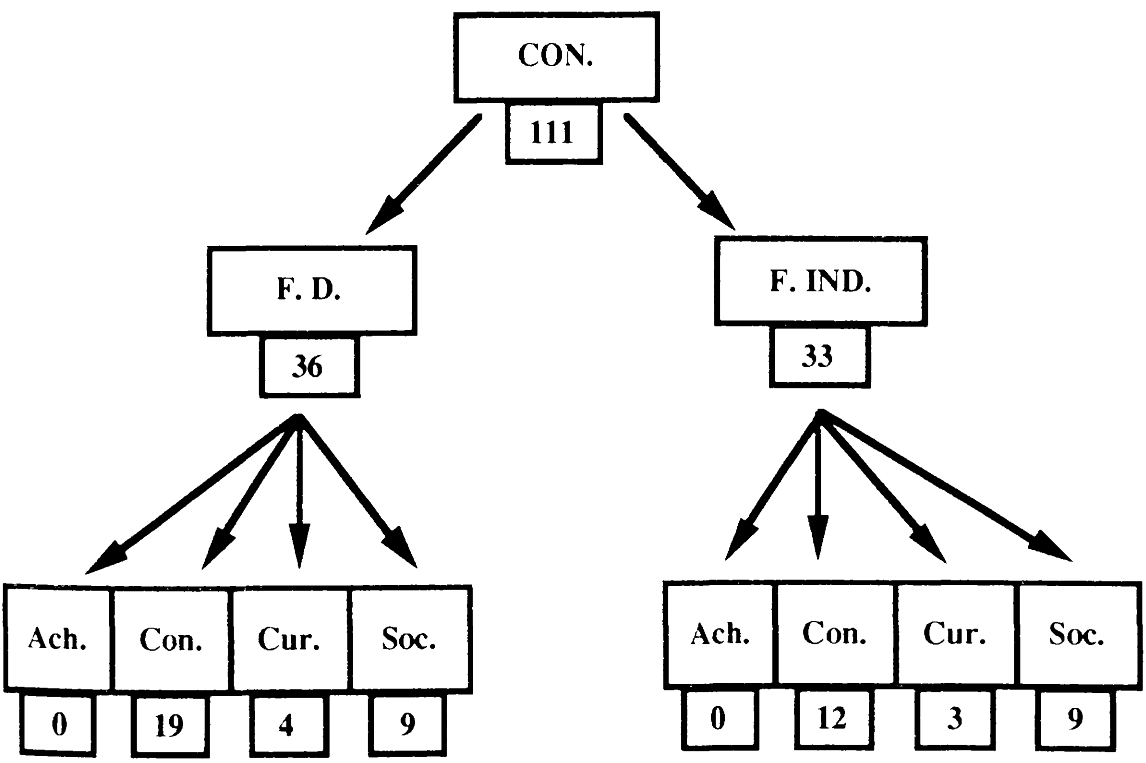


Figure 5.8 The convergent pupils as followed in the involved psychology of this study.

However, such pupils in motivation tests showed a significant trend towards being conscientious in both groups of convergence and divergence which may again confirm that convergent pupils are more likely to hold a conscientious motivation pattern (the dominant one) rather than any other pattern.

Hypothesis (4): The achievement of field-independent pupils of this group (who are convergent thinkers) in practical problem-solving in chemistry may be better than field-dependent pupils of the same group. This could be due to the field-independent thinking style which plays a very important role in dominating the performance and achievement of pupils in tasks.

The final group of pupils is the divergent group (figure 5.9), these pupils are distributed as being field-independent rather than being field-dependent pupils. In the motivation tests, they displayed a similar distribution to the grid of the field-independent group (figure 5.7). The divergent field-independent pupils was displayed equal numbers of pupils participating in the conscientious, curious and social patterns and a small number of pupils in the achiever pattern (because of the small number of original achievers in the sample).

Hypothesis (5): The divergent field-independent pupils could be expected to perform and achieve better in the open-ended tasks rather than the divergent field-dependent pupils, they are more curious, more achiever, more social, and less conscientious than the convergent pupils.

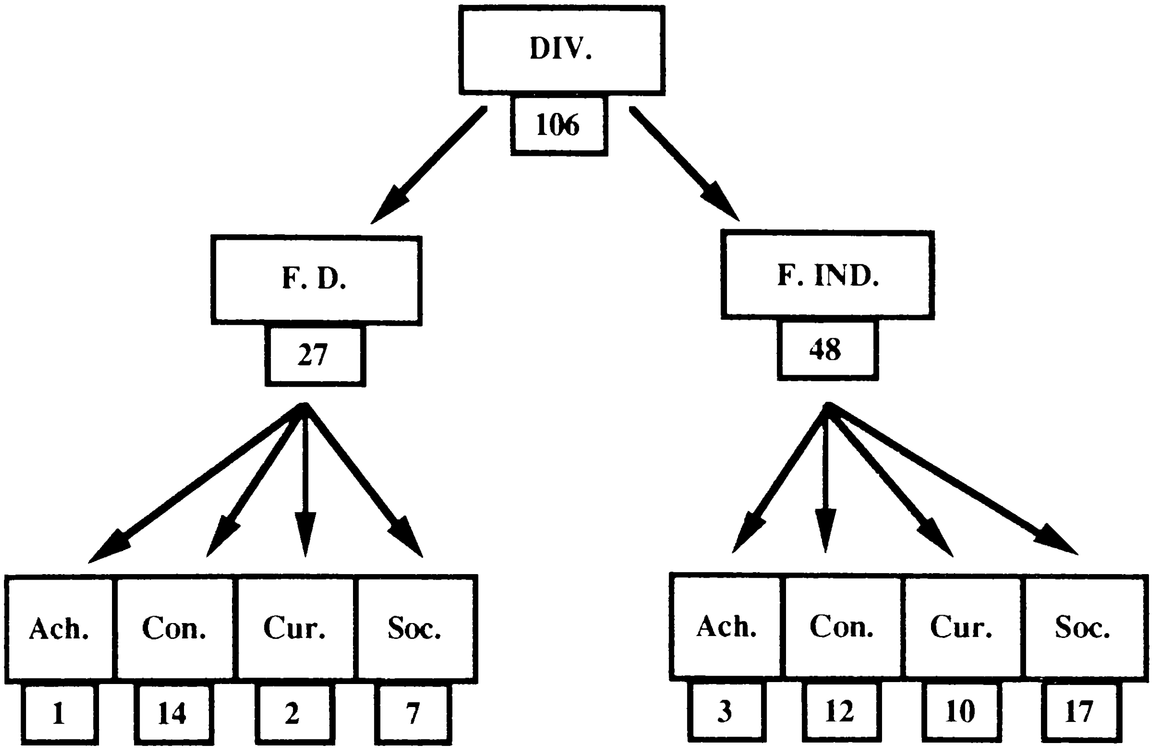


Figure 5.9 The divergent pupils as followed in the involved psychology of this study.

5.5 Summary

The possible correlations obtained from this chapter will be taken as hypotheses to be proved. The field-dependent/field-independent psychological factor correlated positively with the convergent/divergent psychological factor, it indicated that field-independent pupils may be divergent thinking pupils too. Whilst field-dependent pupils showed themselves as more likely to be convergent thinking pupils. Afterwards, such a correlation became more meaningful after the psychology of motivation was inserted into this study.

Any motivational pattern has been found to overlap with at least one more motivational pattern which may indicate that pupils, in general, would have more than one motivational pattern overlapping with other motivational patterns. The highest overlap obtained between patterns was found to be between the conscientious and the social patterns. Other overlaps obtained were found to be between the curious, on one hand, with either the conscientious or the social, on the other hand.

The final picture which emerged from the body of psychology used in the present study agreed with the positive correlation obtained between field-dependent/field-independent and convergent/divergent psychological factors. The motivation factor further elucidated pupils' classifications. The divergent pupil who is more likely a field-independent pupil was found to have a curious or achiever or social motivational preference (having possibly more than one pattern). While the field-dependent pupil who is more likely a convergent thinker was found to have a conscientious or more often a conscientious motivational pattern (may have a social pattern too).

Therefore, several predictions (the five hypotheses) for the pupils' achievements in practical problem solving in chemistry, yet without experimental confirmation, could emerge from this chapter. These predictions will be dealt with in the next chapters in order to from an entire opinion about the effectiveness of the three psychological factors in predicting the pupils learning.

CHAPTER SIX

MINI-PROJECTS IN CHEMISTRY: EVALUATION AND PUPILS' PERFORMANCE

6.1 Introduction

The practical part of this study involves chemistry as a science subject. The present research is attempting to find a chemistry element that may stimulate pupils to do science in general and chemistry in particular, a chemistry that may permit pupils to perform competently to achieve and to allow room for creativity. Accordingly, it was decided that mini-projects in chemistry[134] should be used for the present research. Such projects are believed[25] to be capable of stimulating pupils' creativity by engaging them in various activities which have an extensive motivational effect.

Mini-projects are a new element proposed for the Standard Grade chemistry courses in Scottish secondary schools. The evaluation of such projects is still in progress. Nevertheless, the researcher intended to work out a method for assessing the mini-projects designed only for the purposes of research. It would enable the research to relate the pupils' achievement in the mini-projects to psychological measurements. It is intended in this chapter to display only the pupils' performance and achievement in mini-projects (chemistry) without attempting to relate it with psychology. But in the next chapter such a connection will be taken into consideration when the whole picture will be drawn together in order to find out what sort of learning and attainments would take place amongst various pupils in the schools' laboratories and by involving them in performing such activities .

6.2 The Research Assessment Method of the Mini-Projects

In designing the mini-projects, Hadden (1990)[152] has demanded that a special emphasis be given to assessing abilities which are peculiar to mini-projects, rather than merely repeating the assessment procedures which are carried out in school science.

Each mini-project may require of the pupil several abilities in order to tackle the problem and reach the solution. Hadden (1990)[152] has underlined many abilities which may be needed in performing the mini-projects such as:

I - A pupil would need the ability to understand the nature of the problem given which should be compatible with the setter's intention.

II - A pupil would require some information (relevant to the solution of the problem) from the 'long-term memory' to be retrieved and transferred to the 'working memory'. At the same time, an ability to differentiate between the relevant from irrelevant materials involved in the problem (a separation between the 'signal' and the 'noise') would be necessary.

III - Another ability would be to use some heuristical method in order to facilitate the route to the solution. For example, breaking the problem into sub-problems, using trial and error and working backwards.

IV - The creative thinking ability could be shown in doing mini-projects by selecting and setting up apparatus, controlling variables and by carrying out the working strategy at the bench.

V - A pupil would need the ability to make observations, deductions, and conclusions and, if necessary, the ability to revise strategies in the light of experience.

VI - The ability to write up a lucid report which includes the work that has been done and the solution.

VII - A pupil would need an evaluating ability to evaluate the results obtained from the work and to find whether such results are compatible with the nature of the problem.

Some of these abilities may be required too in the classroom activity, but others may not be employed outside the realm of the laboratory. Thus, the present study preferred to use mini-projects as a chemistry body rather than conventional chemistry which may habitually be found in the classroom. Moreover, the study used mini-projects and not any other practical work activity in the laboratory because mini-projects could provide pupils with an excellent opportunity to employ and show their practical problem-solving abilities. In particular, mini-projects could provide an opportunity for pupils to show a creative thinking ability (or may encourage the pupils' creativity) which may not be stimulated when pupils are involved in normal activities at the laboratory.

6.2.1 The Procedure Employed

The researcher started his assessment method of mini-projects by a number of trials of some projects from the mini-projects booklet[134] in the five schools involved in the present research.

6.2.1.1 The Difficulties Found

In designing an appropriate method for mini-projects assessment, a number of difficulties were found:

I - Pupils were asked to work in pairs in the laboratory to tackle mini-projects. Generally, schools are not able to provide enough apparatus or materials to allow pupils to work individually. The assessment of the pupils' work (in pairs) therefore is extremely difficult. It will not be easy to find out which of the pupils has figured out a certain stage in the work towards the solution of a project.

II - The researcher found that the solutions of some projects are obtainable once the apparatus of such a project are supplied. In other words, it was found that by giving pupils in advance the complete apparatus of some mini-projects (in the booklet) will be sufficient to direct pupils towards the proper solution of such projects. Mini-projects were designed to stimulate the pupils' creativity to innovate and to explore solutions. Therefore, the apparatus must not be supplied until pupils ask for it.

III - The third difficulty found in the work was the amount of help (hints) which may be given to the pupils during the execution of the tasks. Three kinds of help are assumed to be relevant in performing the mini-projects: (i) experimental assistance (ii) factual help (iii) encouragement. It is believed that a precise procedure for counting the amount of help given to the pupils during the work is essential for assessment purposes.

6.2.1.2 A New Design for the Mini-Projects Sheets

Due to the difficulties found in some trials of projects in the schools' sample, the researcher proposed a new design for the projects selected from the mini-projects booklet(134) to be used in the schools. A sample of a project sheet before alteration is shown in figure 6.1, and a sample of the same project after alteration (the new design) is shown in figure 6.2.

The alteration in the sheet design (figure 6.2) provides more facilities for assessment even when pupils are working in pairs or in threes. Each pupil in a pair or in a group of three will have a single sheet of a problem (project). The problem has been set up in section 1 in the new sheet design and is written in the same way as the original sheet design (figure 6.1).

A gap in section 2 is provided for pupils to write their first thoughts or plan which may come to the pupils' minds to solve such a problem. The three vertical boxes opposite to the gap are to be used by a teacher for indicating the frequency of help which has been given to the pupil during setting up the first plan for the problem. The upper box is specified for the amount (frequency) of the experimental help given or needed, for example, setting up some apparatus or explaining the function of the apparatus. The middle box is specified for the amount (frequency) of the factual help given or needed, such help would concern knowledge and understanding of the general concepts and principles of chemistry, it depends upon what knowledge pupils have. The lower box is specified for the amount (frequency) of the encouraging help given or needed. It is prudent to mention here that the encouraging help is not as vital as the experimental or information help and thus any assessor, in assessing mini-projects, must differentiate between the level of importance of the help given to the pupils, and if the frequency of help needed will effect the pupils final scores, then the encouraging help should weigh less in the pupils scores.

Section 3 in the new sheet design of mini-projects concerns the apparatus required for the project or the experiment. This apparatus must be proposed by the pupils themselves to allow more room for creativity and to prevent any hint from being randomly given towards the solution. Providing apparatus in advance for some projects could ruin the main objective of mini-projects (i.e. stimulating pupils' creativity).

NAME: CLASS: PROJECT: 45

1. WHAT YOU ARE ASKED TO DO:

You have to find the best method for getting the coin out of the ice cube without:

a) breaking the ice;
b) using a flame or hot plate;
c) using your own body heat.

You have also to describe the best method you find.

2. WHAT YOU HAVE BEEN GIVEN TO WORK WITH:

Your teacher will tell you what apparatus and chemicals you can use.

You may use any text books, data books or Chemistry notes you think might help you.

3. BEFORE YOU START EXPERIMENTS:

Read what you are asked to do again carefully.

Now write down here any ideas about how you could make a start:

(If you have no ideas at all after you have thought as hard as you can, ask your teacher for some help.)

Now write down here any ideas about how you could continue your experiments.

4. SHOW YOUR IDEAS TO YOUR TEACHER BEFORE YOU START ANY EXPERIMENTS.

Now start your experiments. Use the other side of this page to write up your method, observations, results and conclusions.

Give your Report to your teacher and tidy up your bench.

Figure 6.1 A sample of mini-project before alteration.

NAME: CLASS: PROJECT: 45

1. THE PROBLEM: You have to find the best method for getting the coin out of the ice cube without:
a) breaking the ice.
b) using a flame or hot plate.
c) using your own body heat.
You have also to describe the best method you find.

2. YOUR FIRST PLAN:

Read what you have been asked to do carefully again.
Now write down here your FIRST PLAN for what you intend to do:

(If you have no ideas for a plan after you have thought as hard as you can ask your teacher for some help.)

3. YOUR APPARATUS:

Think carefully about the apparatus you think you will need to carry out your plan as an experiment.
Now write down here a list of the apparatus you think you will need:

Note: You may use any text books, data books or Chemistry notes you think might help you.

4. SHOW YOUR PLAN AND YOUR LIST OF APPARATUS TO YOUR TEACHER BEFORE YOU START ANY EXPERIMENTS. (Your teacher will provide you with the apparatus.)

Now start your experiments. Use the other side of this page to write down your method, results and conclusions. (You should use diagrams or tables to illustrate your results where possible.)

Figure 6.2 A sample of the same mini-project after alteration.

The final section (section 4) in the new sheet design of mini-projects is the actual work section. Another three vertical boxes are provided here to be used for assessment purposes. These boxes concern the frequency of help and are to be used in the same way as they were implemented in section 2 in the project sheet (experimental, factual and encouraging help).

6.2.1.3 The Assessment Sheet of Mini-Projects

The new sheet design of the mini-projects has given the pupil an opportunity to work and to write what he/she intends to do and what he /she did clearly. Moreover, the teacher may find that what the pupils did and obtained in the laboratory is assessable (apart from the practical skills) once the frequency of help is evaluated. However, from the researcher's observations in schools, teachers may find that the administration of mini-projects could become easier if the number of pupils involved in the laboratory does not exceed 15. Any greater number could result in chaos, and prove difficult to organise without assistants.

From the new design of projects, the researcher intends to translate what the pupils did individually (using the teacher's assessment) into the language of scores and therefore an assessment sheet was used for this purpose to constitute all the pupils' performance and achievement. Such an assessment sheet is exhibited in figure 6.3.

Q 1 : Did the pupil have an initial workable plan?	YES	NO					
Q 2 : If NO,					F1	F2	F3
What kind of help was given? Mention the frequency.	Exp.	Fact.	Enco.				
Q 3 : Did the pupil use a novel method?	YES	NO					
Q 4 : Did the pupil need help again during his/her work?	YES	NO			F1	F2	F3
What kind of help was given? Mention the frequency.	Exp.	Fact.	Enco.				
Q 5 : Did the pupil obtain a good result?	YES	NO					
Q 6 : What was the level of difficulty of the problem?	Easy	Fair	Difficult				

F1 = The experimental help frequency.

F2 = The factual help frequency.

F3 = The encouraging help frequency.

Figure 6.3 The assessment sheet used for the mini-projects' assessment in the research.

The assessment sheet of mini-projects comprises of 6 questions. These questions are related to the pupils' work in solving any project. The assessor may use such questions to convert a pupil's work into marks for school assessment purposes:

I - The first technique which has been employed in the assessment method was to give pupils 5 marks, at the beginning of the assessment, for their work in any project whether the project has been accomplished or not. This technique is intended to raise the pupils' scores so that no negative scores were possible, and to allow the assessor (the researcher) to subtract some marks, later in the assessment, from the pupils total scores every time they needed help (as will be seen later).

II - In *question 1* four possibilities in scoring are available (i) YES for a <u>strong</u> initial workable plan which gives a pupil 3 marks (ii) YES for a <u>not bad</u> initial workable plan which gives a pupil 2 marks (iii) YES for a <u>weak</u> initial workable plan which gives a pupil 1 mark (iv) and NO for a <u>wrong</u> initial workable plan which gives a pupil no mark (zero). Such a distribution of marks is believed to be fair since the first thought is deemed to be very important for the work, it is also fair because the pupils have to set up their initial plan individually. A pupil with a weak plan may need help, but if so the researcher recommended not to give him/her 1 mark, instead such a pupil will be considered as having an unworkable plan (no mark should be given). Therefore a clear line between a workable plan (whether it is strong/not bad/weak) and an unworkable plan could be drawn to prevent any confusion in assessment.

III - *Question 2* concerns <u>only</u> the pupils who were given zero in question 1. Such pupils will be classified as needing help, and the help must be identified and counted. Therefore, the assessor may realise, from the project sheet, what sort of help was given to the pupil (experimental, factual, and encouraging help), and how often (frequency). The researcher decided to subtract a mark from a pupil (each pupil has already got 5 marks from the researcher at the beginning of the assessment) every time the experimental or factual help was given. A half mark will be subtracted from a pupil's score every time encouraging help is given. The experimental and factual help are considered to be more important and effective towards obtaining a workable plan than the encouraging help and thus 1 mark is subtracted from the pupils' scores when the experimental and factual help are needed, while half a mark is subtracted from the pupils' scores when the encouraging help is needed.

IV - In *question 3* the researcher intends to find out whether any creative thought or method has been employed in the experiment. One mark is for the answer YES, and no mark (zero) for the answer NO. It is a bonus which has been decided for any pupil who brings creative thought towards a solution.

V - In *question 4* the pupil can get 2 marks if he/she finished the experiment without further help from the teacher (answer NO), but the pupil may need help during the actual work (answer YES) and if so, the same procedure of subtracting and awarding marks will be used (as administered in III above). The subtraction in this stage will be in half marks rather than in full marks and in all the three boxes. To justify this, it is believed that the experimental and information help in this stage are not as vital as at the beginning of the work (during the initial plan) while for the encouraging help, the researcher believes that the pupil in this stage should be more independent than at the beginning of the work and he/she should not need much encouragement. Thus, to subtract a half mark from the pupil for the given encouraging help could be rational.

VI - In *question 5* four possibilities in scoring are available (i) YES for a strong result which gives a pupil 2 marks (ii) YES for a not bad result which gives a pupil 1.5 marks (iii) YES for a weak result which gives a pupil 1 mark (iv) and NO for a wrong result which gives a pupil no mark (zero).

VII- In *question 6* the level of difficulty of each project could be assessed from the teachers' point of view. Teachers are considered to play a very important role in evaluating the level of difficulty of each mini-project because they are so close to the pupils and they may give a precise estimation for such projects. The teacher is asked to write on the pupils' sheets the numbers 1, 2, and 3 which indicate the level of difficulty of the projects. 1 Means that the project is easy and therefore no extra mark will be awarded to the pupil, 2 means that the project is fair and therefore 1 extra mark will be awarded to the pupil, and 3 means that the project is difficult and 2 extra marks will be awarded to the pupil for performing such a project.

The highest score that could be obtained by the pupil from such an assessment method is 15 marks in each mini-project (10 marks from the assessment of the actual work of the pupils plus 5 extra marks which were given to all pupils at the beginning of the assessment). The marking scheme which was explained above is shown in figure 6.4 on the assessment sheet.

Q 1 : Did the pupil have an initial workable plan?	Strong +3	Not bad +2	Weak +1	YES	NO	Wrong 0			
Q 2 : If NO,							F1	F2	F3
What kind of help was given? Mention the frequency.			Exp.	Fact.	Enco.		-1	-1	-0.5
Q 3 : Did the pupil use a novel method?			+1	YES	NO	0			
Q 4 : Did the pupil need help again during his/her work?			0	YES	NO	+2	F1	F2	F3
What kind of help was given? Mention the frequency.			Exp.	Fact.	Enco.		-0.5	-0.5	-0.5
Q 5 : Did the pupil obtain a good result?	Strong +2	Not bad +1.5	Weak +1	YES	NO	0			
Q 6 : What was the level of difficulty of the problem?			Easy 0	Fair +1	Difficult +2				

F1 = The experimental help frequency.

F2 = The factual help frequency.

F3 = The encouraging help frequency.

Figure 6.4 The marking scheme on the assessment sheet of the mini-projects.

This marking scheme has been used in the five schools involved in the research, and it was capable of being translated into pupils' numerical scores for assessment. Nevertheless, this method, as stated before, was employed only for the present research assessment purposes and not for class room assessment for examination purposes.

6.3 The Administration of Mini-Projects in Schools

It is worth explaining how mini-projects were administered in the schools selected for the study.

Due to the lack of apparatus or other facilities in schools, the pupils were divided into a certain number of pairs in order to do mini-projects. Each pair of pupils was asked to do a project which was different from the other projects used in the same session in the laboratory.

At the beginning of the session, a teacher explained what pupils must do with the given sheets. Each pupil in the laboratory was handed a mini-project sheet which represented a problem (there are twin sheets for every single project involved in the session), and as yet no one should know his/her partner. The research aimed to allow pupils to write their own initial thoughts and plan to solve the given problem. The pupils were permitted to use any text books or chemistry notes which might be useful or helpful. After a certain time (depends upon the teacher), the teacher started assessing the pupils' plans using the upper column of boxes in the pupils' sheets. Help and hints should be given for those who stuck in the first phase of the work (of course with recording the frequency of help in the boxes provided). Moreover, teachers had to check the safety of the plan. At the end of this stage, every pupil should have a proper plan ready for testing to find out a solution.

Lots of interactive discussions between the teacher and the pupils emerged during this stage which added a great many advantages to the learning procedures of pupils. Such discussions created a good atmosphere for stimulating, retrieving, manipulating, and evaluating chemical concepts and principles which enriched the pupils' knowledge and understanding of chemistry as well as developing their attitudes towards science.

In this stage pupils also had to write what apparatus was required for the execution of the experiment? Having finished all this (part 1, 2, and 3 of the project sheet), pupils were now ready to join their partners for the actual practical work and to solve the mini-project (the problem).

In the next phase of the laboratory work the teacher instructed each pupil to work with a partner who is going to be named for the first time. The pupils in each pair discussed together a best plan for tackling the given problem. It was possible to notice for any pair that one of the pupils became dominant and the other pupil became a follower in accordance with their level of intelligence and cleverness in the subject (it seems that pupils estimate such levels in each other from daily progress and communication in any given subject). However, a single agreed plan finally emerged from the pair nominated for the experimental work. The teacher checked the agreed plan for safety and gave the green light to start the job.

The third phase comprised of the actual work (part 4 of the project sheet). In this phase pupils set up the apparatus and started doing the experiment. They might need help in some stages and thus teachers could assess such help given and using the lower column of boxes in the project sheet to record the frequency of help if any, and by a similar procedure to the previous one which was applied in section 2 of the project sheet.

In the instruction part of the mini-project booklet, Hadden and Johnstone (1990)[(134)] have specified up to one hour (or a duration of a 'double period' if periods are of 30-35 minutes duration) as a time limit for such projects. Therefore, each pair should be advised to keep some time before the end of the laboratory session for the writing up of the actual work done with the conclusions and diagrams if any. The pupils could use the back of the project sheet to write their procedures and conclusions.

At the end of the period, all sheets were gathered from the pupils. The assessor (the researcher here) then converted the written materials and the frequency of help given into numerical scores by using the marking scheme shown in the assessment sheet of the mini-projects (figure 6.4).

6.4 The Pupils' Attainments in the Mini-Projects

Having prepared a plan for the evaluation of mini-projects, practical sessions of mini-projects took place in each school selected for the present study. The sample of schools was asked to do a mini-project for research purposes and not only for the school purposes. Schools were free to select a number of projects from the booklet for testing on their pupils in accordance with each school's facilities and equipment available.

It is intended in this chapter to show only the performance and achievements of the pupils in mini-projects and therefore no correlations between such a variable and the psychological variables studied in the previous chapters will be plotted or measured. All possible correlations will be discussed in the next chapter.

Samples of the pupils answers in mini-projects which were obtained during the practical sessions administered in schools are exhibited in figure 6.5 (a), (b), and (c). Moreover, additional samples of the mini-projects answers are to be shown in appendix 5.

2

1. THE PROBLEM:

You have to produce exactly 1 cm^3 of pure water from the coloured water.

---

2. YOUR FIRST PLAN:

Read what you have been asked to do carefully again.
Now write down here your FIRST PLAN for what you intend to do:

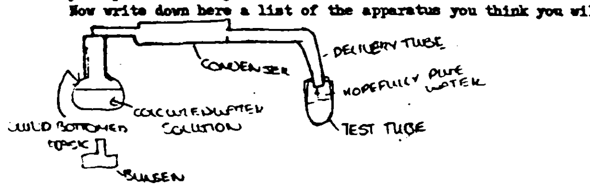
To solve this problem I would heat up a sample of coloured water until it boils were evaporation will occur and collect the pure water along a delivery tube as the colour will hopefully not evaporate

(If you have no ideas for a plan after you have thought as hard as you can ask your teacher for some help.)

---

3. YOUR APPARATUS:

Think carefully about the apparatus you think you will need to carry out your plan as an experiment.
Now write down here a list of the apparatus you think you will need:



DELIVERY TUBE
CONDENSER
BUNSEN
TEST TUBE
ROUND BOTTOMED FLASK
THERMOMETER

Note: You may use any text books, data books or Chemistry notes you think might help you.

---

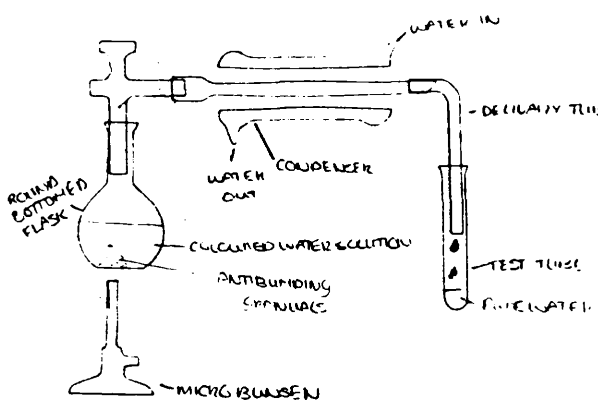
4. SHOW YOUR PLAN AND YOUR LIST OF APPARATUS TO YOUR TEACHER BEFORE YOU START ANY EXPERIMENTS. (Your teacher will provide you with the apparatus.)

Now start your experiments. Use the other side of this page to write down your method, results and conclusions. (You should use diagrams or tables to illustrate your results where possible.)

AIM: To separate 1cm³ of pure water from a coloured water solution.

METHOD - We did our experiment by boiling the solution of water and colouring. This produced a gas which we passed along a condenser. The condenser cooled it down rapidly and changed it into water again this collected in a test tube at the bottom of the delivery tube and we then measured it out.

The equipment we used was as follows a round bottomed flask, condenser, micro bunsen, delivery tube, test tube, anti-bumping granules



CONCLUSIONS

1) You can separate water from a coloured solution using Distillation

2) The changes which take place in Distillation are Evaporation → Condensation

Figure 6.5 (a) A sample of a pupil's answer in a mini-project.

1. THE PROBLEM:

You have to find which drop has the larger volume: the drop from the burette or the drop from the pipette.

---

2. YOUR FIRST PLAN:

Read what you have been asked to do carefully again.
Now write down here your FIRST PLAN for what you intend to do:

Measure a drop from the burette and a drop from a pipette on a very accurate measuring cilinder by adding more of the [illegible] (equal) to both cilinders [illegible]

(If you have no ideas for a plan after you have thought as hard as you can ask your teacher for some help.)

---

3. YOUR APPARATUS:

Think carefully about the apparatus you think you will need to carry out your plan as an experiment.
Now write down here a list of the apparatus you think you will need:

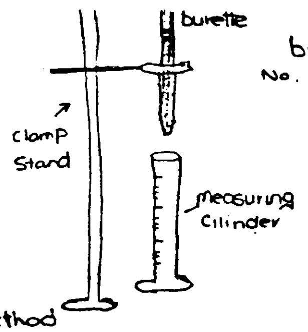
pipette
burette
two measuring cilinders
liquid
Clamp stand
syringe.

Note: You may use any text books, data books or Chemistry notes you think might help you.

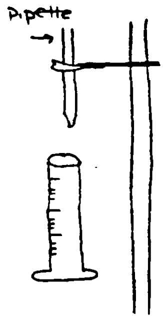
---

4. SHOW YOUR PLAN AND YOUR LIST OF APPARATUS TO YOUR TEACHER BEFORE YOU START ANY EXPERIMENTS. (Your teacher will provide you with the apparatus.)

Now start your experiments. Use the other side of this page to write down your method, results and conclusions. (You should use diagrams or tables to illustrate your results where possible.)



	burette	pipette
No. Drops	218.	198



Method

To do this experiment we used a pipette, burette, clamp stand, syringe, water, two measuring cilinders

We filled the pipette up with water and counted the number of drops till the water level on the measuring cilinder reached 10 cm³.
We done the same for the burette.

Results

The pipette took 198 drops to full to 10 cm³ but the burette took 218.

Conclusion

The pipette has a larger volume per drop than the burette.

Figure 6.5 (b) A sample of a pupil's answer in a mini-project.

3

1. THE PROBLEM:

A manufacturer is designing a new machine which will supply cups of tea when a coin is put into the machine.

You have to find out which of the types of sugar you have been given is the best one to use in the machine.

2. YOUR FIRST PLAN:

Read what you have been asked to do carefully again.
Now write down here your FIRST PLAN for what you intend to do:

I intend to test all the three sugars, to see which ones do what. i.e. Brown sugar may not be soluble, icing sugar may ~~[illegible]~~ be soluble etc. Once I have done this I will think of how hot the water would be and if the sugar is going to make difference to the sweetness of it (if it is not soluble). I will first see if they are all soluble and then heat them to see if they ~~[illegible]~~ melt at a low or high heated boiling point. I would also weigh each out ~~[illegible]~~ equally to get a fair result.

(If you have no ideas for a plan after you have thought as hard as you can ask your teacher for some help.)

3. YOUR APPARATUS:

Think carefully about the apparatus you think you will need to carry out your plan as an experiment.
Now write down here a list of the apparatus you think you will need:

Beakers
Bunsen burner
stirring rod.
Water. (hot)
Sugars.
Tripod.
Wire gauze.
Teabags.

weighing machine
Spatula.
measuring cylinder
3 cups
Thermometer

Note: You may use any text books, data books or Chemistry notes you think might help you.

4. SHOW YOUR PLAN AND YOUR LIST OF APPARATUS TO YOUR TEACHER BEFORE YOU START ANY EXPERIMENTS. (Your teacher will provide you with the apparatus.)

Now start your experiments. Use the other side of this page to write down your method, results and conclusions. (You should use diagrams or tables to illustrate your results where possible.)

We weighed the sugars out equally to 1·00g. We had taken into consideration the weight of the cups. We put a Lipton tea bag into a beaker and made tea. It was at a temperature of 90°C when we measured out some of tea into each cup. We then looked to see how fast they dissolved and we stirred all the cups equally for 5 secs. When we looked our results were as follows.

Name of sugar	how fast it dissolved (1st, 2nd or 3rd)
Granulated	1st
Brown	3rd

The apparatus was set up as shown below:

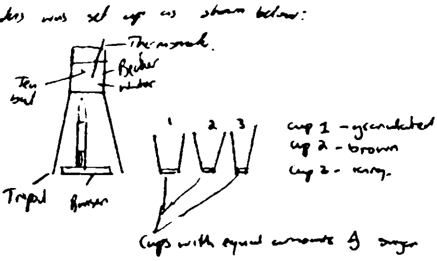


Figure 6.5 (c) A sample of a pupil's answer in a mini-project.

After each practical session, the pupils sheets were gathered and assessed according to the research assessment plan which was mentioned earlier. It took about a year of this research to get all the sample from the five schools (217 pupils) tested in the mini-projects. The mean score and the standard deviation of the sample's attainments in the mini-projects are shown in table 6.1. In addition to that a scatter diagram of the pupils' scores in the mini-projects versus the frequency and number of pupils who obtained such scores is plotted as could be seen in figure 6.6.

Table 6.1

The sample mean score and standard deviation in the mini-projects

No. of pupils in the sample	Mean score	Standard deviation
217	9.07	2.49

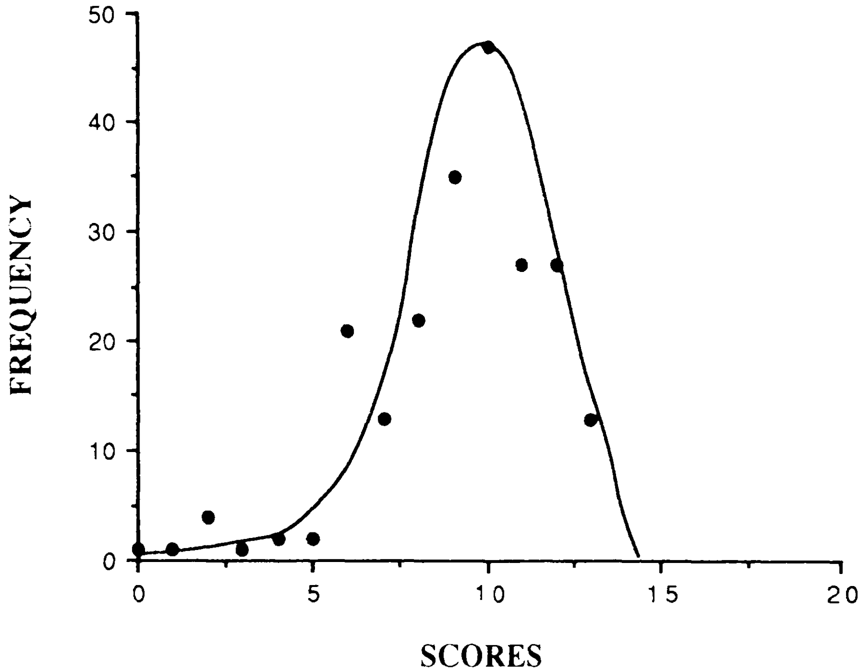


Figure 6.6 The sample scores in the mini-projects versus the frequency number of pupils.

6.5 Summary

The study has created its own method of assessment for a new practical problem-solving element in the school chemistry called mini-projects. According to this assessment method, pupils' work could be assessed in a scale of 15 marks. Such a method would not be affected if pupils are asked to work individually or in pairs or threes.

In fact, the way to assess pupils doing projects together in a laboratory is deemed to be extremely difficult. The pupils' collaboration in working in a laboratory would demand a number of teachers to supervise, help and assess pupils. At the end of the day, teachers would find themselves forced to use the pupils responses (sheets) as the best material production to represent the pupils achievement. It would be rather difficult to record the help given to the pupils during the work. Moreover, the creativity in thinking and in designing experiments would have no room in the normal practical work in the laboratory. Thus, the research method of assessment was keen not to ignore any contribution from either the teacher or the pupil. In this way it was possible to draw a clear picture of the performance and achievement of pupils whether they were working in threes, in pairs or individually.

There are several abilities involved in the mini-projects[152], the assessment method of the present study aimed to assess as many as possible of such abilities, it relies on chemistry, on one hand, and on education and psychology, on the other hand. The assessment sheet of mini-projects is devoted to the measurement of the pupils' chemistry achievement and their creativity in doing and designing experiments in the laboratory.

CHAPTER SEVEN

THE RELATIONSHIPS BETWEEN MINI-PROJECTS ATTAINMENTS AND VARIOUS PSYCHOLOGICAL FACTORS USED IN THE RESEARCH

7.1 Introduction

The ultimate situation in this piece of work will be reached when the pupils' attainments throughout the mini-projects are placed against their achievement in the various psychological tests which have been employed in the study. It is by plotting all the variables involved in the research against each other that the researcher may discover new correlations which emerge and result in new hypotheses for science education.

The five hypotheses which are raised in chapter five need now to be either supported or rejected. This chapter will deal with such hypotheses and will discuss any other results which may be obtained.

Having classified pupils into certain categories according to the psychological factors used (in the previous chapters), it is necessary to follow the pupils in their performance in practical problem-solving in chemistry. It should enable us to understand what is the nature and the level of performance of each group in mini-projects or in other activities which require creative thinking ability.

The final production of such work may assist educators to place emphasis upon the needs of pupils in secondary level when they perform practical problem-solving in chemistry, it may also underline the faults and defects of the general schools' practical activity (syllabi, planning, and objectives) compared to the use of creative tasks such as mini-projects. Moreover, this may remind and stimulate the thinking of educators in what kinds of teaching are essential to enhance creativity, and of the degree of attention which must be given to different categories of pupils in their learning processes.

7.2 Plotting the Field-Dependent/Field-Independent Thinking Styles of Pupils Versus the Mini-Projects Attainments

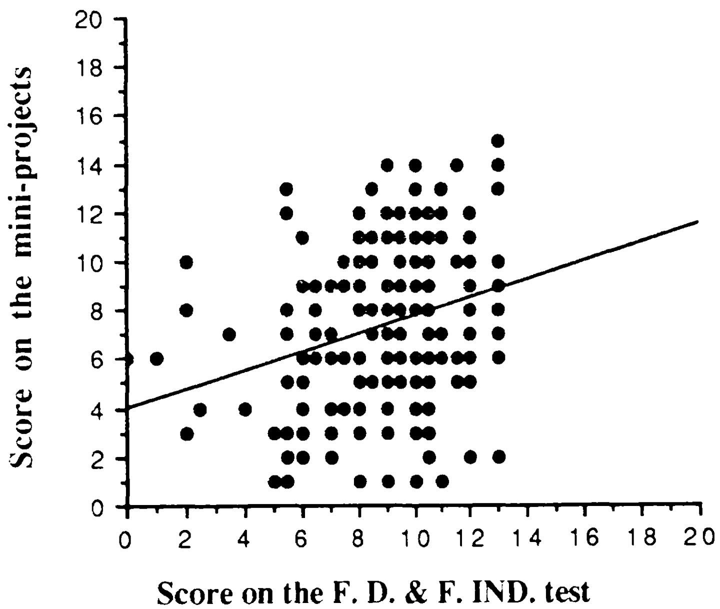
The field-dependent/field-independent psychological factor was used in the researcher's previous work[1, 13]. It was plotted versus the pupils' and students' achievement in conventional chemistry examinations and resulted in a positive correlation between the two variables.

However, no attempt was made in that early work to correlate between the field-dependent/field-independent factor, on one hand, and the chemistry which is involved in practical work or problem-solving such as mini-projects. Therefore, it is worth looking for any correlation which could be obtained between the field-dependent/field-independent factor versus practical problem solving in chemistry factor - especially those - which require a creative thinking ability from the pupils such as the mini-projects in chemistry?

Accordingly, the pupils' scores in the mini-projects have been plotted as a variable versus their field-dependent/field-independent score as the other variable with the result that a very significant correlation emerged as the Pearson Product-Moment Correlation Coefficient (r) was 0.30. The null hypothesis[153, 154] could then be rejected at a 0.1% level. Figure 7.1 shows such a correlation.

This indicates that pupils who scored highly in the mini-projects practical work tend to be field-independent while pupils who obtained low scores in such projects tend to be field-dependent. Similar correlations emerged from the researcher's previous work[1, 13], the pupils' scores in the field-dependent/field-independent test correlated significantly with their scores in the conventional chemistry examinations.

It is evident from the present study that there is a stronger correlation between field-dependent/field-independent and mini-projects (score 0.1%) than the correlation between field-dependent/field-independent and conventional chemistry examinations (score 5%). This fact is apparent between the two variables (mini-projects and field-dependent/field-independent variables) from studying the degree of confidence in the rejection of the null hypothesis[153, 154] which appeared to be at the 0.1% level in the mini-projects situation, whilst the null hypothesis was rejected at the 5% level in the conventional chemistry examinations situation[1].



Pearson Correlation = 0.30 Degrees of freedom = 215 Tail probability = 0.00

Significant at a **0.1%** level.

Figure 7.1 The pupils' score attainments in the mini-projects versus their scores in the field-dependent/field-independent test.

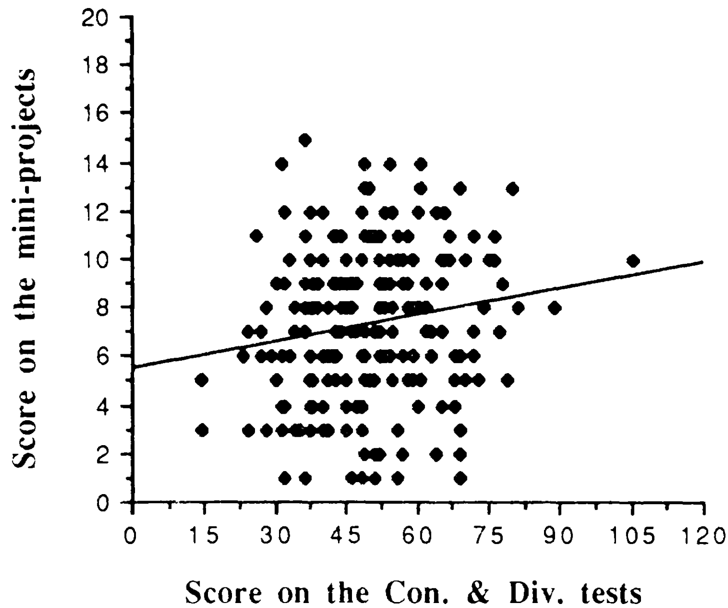
7.3 Plotting the Convergent/Divergent Thinking Styles of Pupils Versus the Mini-Projects Attainments

The next stage of this work is to study the relationship between the convergent/divergent thinking styles of pupils and their attainments in the mini-projects in chemistry. It is intended to allow us to understand whether pupils whose ability consists of a narrowing in focus, a winnowing down of detail and an imaginative austerity (convergent pupils), will perform and achieve better in the mini-projects than the pupils who have an "ability to synthesize and recombine material to form new solutions to problems (divergent pupils)" [60].

As a response to the above question, the researcher plotted the pupils' scores in the convergent/divergent tests versus their scores in the mini-projects as exhibited in figure 7.2.

Pupils who obtained high scores in the convergent/divergent tests (divergent pupils) obtained again high scores in the mini-projects, while the pupils who obtained low scores in the convergent/divergent tests (convergent pupils) obtained low scores in the mini-projects too. The scatter diagram in figure 7.2 shows a very significant correlation ($r = 0.29$) that emerged from plotting the two variables against each other: the null hypothesis[153, 154] could therefore be rejected at a 0.1% level.

It seems that the convergent thinking ability may not assist pupils in performing practical problem-solving in chemistry particularly when the practical tasks require a creative and imaginative thinking ability.



Pearson Correlation = 0.29 Degrees of freedom = 215 Tail probability = 0.00

Significant at a **0.1%** level.

Figure 7.2 The pupils' score attainments in the mini-projects versus their scores in the convergent/divergent tests.

Building on what has emerged so far in this section, (i) pupils who are field-independent seemed more likely to be divergent thinking pupils (both performed well in the mini-projects) as appeared from figure 7.1 and 7.2, on the one hand, and (ii) pupils who are field-dependent seemed more likely to be convergent thinking pupils (both not performed well in the mini-projects) as appeared from figure 7.1 and 7.2, on the other hand. It has emerged statistically (as shown in table 7.1) that the field-independent pupils of the researcher's sample tended to be divergent pupils (59% of the field-independent pupils were divergent pupils), whereas the field-dependent pupils of the research's sample tended to be more likely convergent pupils (57% of the field-dependent pupils were convergent pupils). These results (in table 7.1) are significant at better than a 10% level as the Chi-square value is equal to 3.19.

Table 7.1

The percentage of field-dependent and field-independent pupils who are at the same time convergent or divergent thinkers

Groups	F. D. N = 63	F. IND. N = 81
Con.	36 57%	33 41%
Div.	27 43%	48 59%

However, these linkages will be discussed further in the next sections of this chapter to enable this research to form a final picture about the sample of pupils.

7.4 <u>The Motivational Patterns of Pupils Versus the Mini-Projects Attainments</u>

The third psychological factor which has been used in this study is the motivation factor. The sample of the research was divided earlier in chapter four into four motivational patterns; the achiever, the conscientious, the curious, and the social.

The patterns competed against each other for the highest achievement in the mini-projects. It was aimed to find out whether these motivational patterns of the pupils had any influence on their performance in mini-projects.

The results showed that the achievers obtained the highest mean score, the curious came in the second place, the social and the conscientious obtained almost the same mean score. However, the social came marginally in the third place and the conscientious in the fourth place. Table 7.2 exhibits these mean scores of the pupils' motivational patterns.

Table 7.2

The mean scores of the pupils' motivational groups in the mini-projects

Motivational Patterns N = **178** *	The Mean Scores in Mini-Projects	The Standard Deviation
The Achiever N = **11**	**10.95**	**2.01**
The Conscientious N = **78**	**8.79**	**2.22**
The Curious N = **32**	**9.96**	**1.93**
The Social N = **57**	**8.91**	**2.66**

* Total number of pupils who were categorised as belonging to certain motivational patterns. 39 Pupils of the total number of the sample (N = 217) were ignored by the study either because they did not attend any motivation test (N = 4) or did not clearly belong to any motivational pattern (N = 35).

These results are consistent with attributes found in the literature[21, 74, 83, 85, 86]. The achiever pupil was in the first place, he/she is more able than others to obtain high scores in the mini-projects. This could be due to the fact that the achiever thinking style is more likely to be a field-independent and a divergent style (see figures 5.7, 5.9, pages 135, 138 respectively) which aids him/her in achieving well in practical problem-solving in chemistry.

Following in second place was the curious pupil. This pupil is eager to do practical problem-solving and is capable of creating relevant thoughts for solving such tasks. The curious pupil is also more likely to be a field-independent and a divergent thinker (see figures 5.7, 5.9, pages 135, 138 respectively). Thus, it will be expected that such a pupil could perform well in the mini-projects.

The ranking of the conscientious and social pupils was the last in the competition for the highest score in mini-projects. Both pupils achieved similarly, but the social pupils obtained a slightly higher mean score than the conscientious one. Such a difference between both mean scores is not significant but it shows, to a slight extent, that the social pupil may perform better than the conscientious pupil in mini-projects. The social pupil may enjoy doing mini-projects more than the conscientious and if so, it is due to the nature of each social motivational preference. The social pupil likes to participate in any activity which requires groups of pupils working together and he/she does not mind participating in learning activities such as the mini-projects, while the conscientious pupil feels insecure in performing such activities which have no instructions and it is of no consequence whether he/she is asked to work in a group of pupils or individually. Moreover, it has been found (see figures 5.7, 5.9, pages 135, 138 respectively) that the social pupil is more likely to be a field-independent and a divergent thinker, while the conscientious pupil is more likely to be a field-dependent and a convergent thinker. Thus, the social pupil could be expected to perform better than the conscientious pupil in mini-projects.

7.5 The Interaction between Field-Dependent/Field-Independent and Convergent/Divergent Learning Styles and their Effectiveness on the Achievements of Pupils in Mini-Projects

In order to understand the various possible patterns which may emerge from correlating all the psychological factors involved in the present study versus each other and versus the pupils' achievements in mini-projects at the same time, the researcher intends to study such possibilities of patterns in the following sub-sections.

7.5.1 The Attainments of Field-Dependent/Divergent and Field-Dependent/Convergent Pupils in the Mini-Projects

According to **hypothesis (1)** which has been set out in chapter five (the divergent field-dependent pupils may be expected to achieve better at practical problem solving in chemistry such as the mini-projects compared to the convergent field-dependent pupils).

The mean scores of field-dependent/divergent (FD.DIV) and field-dependent/convergent (FD.CON) pupils in mini-projects are set out in table 7.3. It is evident from table 7.3 that the FD.DIV pupils performed and achieved better in mini-projects than the FD.CON pupils which may support, to some extent, what was predicted in **hypothesis (1)**. However, the difference in the mean scores between both groups is not significant, but it is still an indication which may show that FD.DIV pupils are more capable than their FD.CON colleagues in dealing with projects which require a creative thinking ability.

Although a pupil may have a field-dependent thinking style, being divergent in his/her way of thinking could be more helpful than being convergent in tackling chemical problems which by their nature require some sort of a creative thinking ability.

Table 7.3

The mean scores of FD.DIV and FD.CON pupils in the mini-projects

Groups	FD. DIV. N = 27	FD. CON. N = 36
Mean scores in the Mini-Projects	**8.8**	**7.5**

7.5.2 The Attainments of Field-Independent/Divergent and Field-Independent/Convergent Pupils in the Mini-Projects

Having studied the performance of FD.DIV and FD.CON pupils in the mini-projects, it is beneficial now to study the performance of field-independent/divergent pupils (FIND.DIV) and field-independent/convergent pupils (FIND.CON) in the mini-projects too in order to understand the differences between the various learning styles in performing the mini-projects.

According to **hypothesis (3)** which has been set out in chapter five (the field-independent convergent thinkers could be expected to display a poorer performance and achievement in practical problem-solving in chemistry compared to the field-independent divergent thinkers). It is a prediction which may place an emphasis on the preference for being a divergent thinker rather than a convergent thinker in dealing with practical problem-solving in chemistry even though a pupil is field-independent.

The mean scores, as shown in table 7.4, indicate that FIND.DIV pupils performed slightly better than FIND.CON pupils in the mini-projects tasks. Although, the difference between both mean scores is not significant, it may give some support to what has been predicted in **hypothesis (3)**.

Table 7.4

The mean scores of FIND.DIV and FIND.CON pupils in the mini-projects

Groups	FIND. DIV. N = 48	FIND. CON. N = 33
Mean scores in the Mini-Projects	**10.1**	**9.5**

It could be that being field-independent may help you to deal with tasks which require a creative thinking ability. The capability of such pupils may come from their strategies and their ways of handling the materials involved in any problem. In a problem-solving situation, field-independent pupils are more able than others to separate the 'signal' from the 'noise'. Thus, they are using a considerable amount of their *potential* working space capacity in useful processing compared to other pupils who have difficulties in the separation between the 'signal' from the 'noise' and for whom the 'noise' captures some of their potential working space leaving a reduced space for useful processing [(13)].

7.5.3 The Attainments of Convergent/Field-Independent and Convergent/Field-Dependent Pupils in the Mini-Projects

The other way of looking at the data obtained from the mean scores of pupils in mini-projects which have been calculated in the last two sub-sections is by reversing the pictures of the pupils' psychological factors (F.D./F.IND. and CON./DIV. only).

The convergent/field-dependent pupils (CON.FD) obtained low scores in the mini-projects (the mean score = 7.5) compared to their convergent/field-independent colleagues (CON.FIND) (the mean score = 9.5) as shown in table 7.5. This could be interpreted as due to the importance of the field-independent thinking style in pupils as explained in sub-section 7.5.2. Moreover, the results of this sub-section may support the prediction of the research which concerns the achievements of CON.FD and CON.FIND pupils in the mini-projects and as it has been assumed in **hypothesis (4)** in chapter five (the achievement of field-independent convergent pupils in practical problem-solving in chemistry may be better than field-dependent convergent pupils. This could be due to the field-independent thinking style which plays a very important role in dominating the performance and achievement of pupils in tasks).

The researcher was aware from the beginning of the importance of field-dependent/field-independent psychological factor in pupils learning and therefore he used this factor in the study, allowing it to interact with other aspects in psychology, to understand its influence on the performance of pupils in practical problem-solving in chemistry.

Table 7.5

The mean scores of CON.FD and CON.FIND pupils in the mini-projects

Groups	CON. FD N = 36	CON. FIND N = 33
Mean scores in the Mini-Projects	**7.5**	**9.5**

7.5.4 The Attainments of Divergent/Field-Independent and Divergent/Field-Dependent Pupils in the Mini-Projects

According to the mean scores of pupils in mini-projects, the divergent/field-independent pupils (DIV.FIND) performed and achieved better than the divergent/field-dependent pupils (DIV.FD) as shown in table 7.6. Therefore, such results could support the research prediction which has been represented in **hypothesis (5)** in chapter five (the divergent field-independent pupils could be expected to perform and achieve better in the open-ended tasks rather than the divergent field-dependent pupils, they are more curious, more achiever, more social, and less conscientious than the convergent pupils).

Table 7.6

The mean scores of DIV.FD and DIV.FIND pupils in the mini-projects

Groups	DIV. FD N = 27	DIV. FIND N = 48
Mean scores in the Mini-Projects	**8.8**	**10.1**

Being a divergent and a field-independent thinker seems to enhance performance in practical problem-solving. The divergent thinking style would facilitate the pupils' thoughts and would help towards the application of creative thinking styles to the tasks. On the other hand, the field-independent thinking style would promote the processes of the working space capacity by allowing a pupil to benefit from using his/her mental capacity to a greater extent.

It is evident from the present section (7.5) that the various learning styles of pupils had an effect on the pupils' performance in mini-projects. If a vertical line is drawn along the performance of pupils in the projects, the pupils who would be placed at the top of this line would be the FIND.DIV pupils who showed the strongest performances in the projects (the mean score is 10.1), while the pupils who would be placed at the bottom of this line would be the FD.CON pupils who showed the weakest performances in the projects (the mean score is 7.5). The FIND.CON pupils come in the second place along the vertical line, and the FD.DIV pupils come in the third place along the line. Another way of presenting the pupils' groups and mean scores is by distributing them along vertical and horizontal axes as exhibited in figure 7.3.

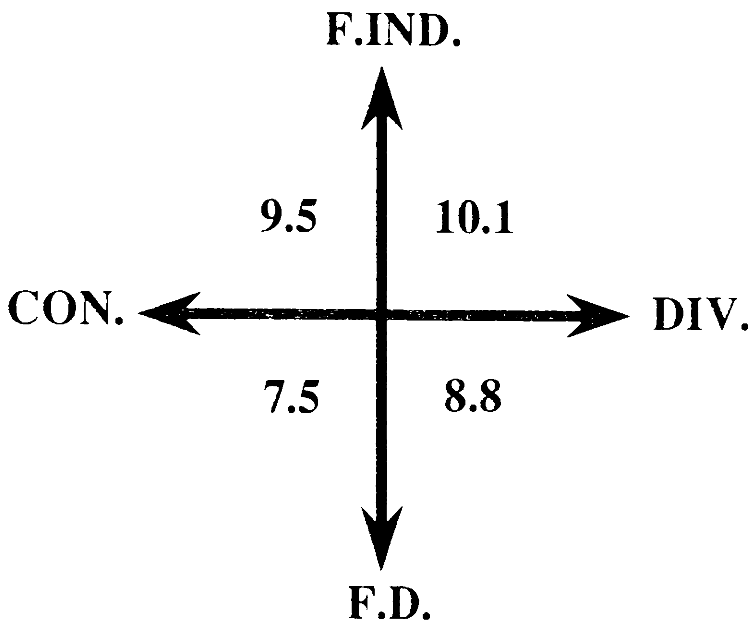


Figure 7.3 Using field-dependent/field-independent and convergent/divergent thinking styles in distributing the mean scores of pupils in mini-projects.

7.6 The Overlapping Results of Field-Dependent/Field-Independent, Convergent/Divergent and Motivation Learning Styles in their Influence on the Performances of Pupils in Mini-Projects

The ultimate picture that this research could reach is when all the learning styles of pupils used in the study are plotted against each other. The results of such a plot would be various groups of pupils with various learning styles.

In fact, it is the aim of the present research to study the influence of pupils' various learning styles with their possible overlapping pictures on the performance of pupils in practical problem-solving in chemistry. This assignment may require a study of the following groups which have emerged earlier in the work (chapter five).

7.6.1 The Study of the Achiever Pupils Group

Achiever pupils is the group which perform best in the mini-projects. However, it is the concern of the research to understand the effectiveness of other learning styles which the achiever pupils may have and their influence on performing practical problem-solving in chemistry.

The achiever group could be divided into five different categories of pupils; (i) the field-dependent/divergent (ii) the field-dependent/convergent (iii) the field-independent/divergent (iv) the field-independent/convergent (v) and the field-intermediate/divergent or convergent achievers (those achievers were omitted from the present study).

Table 7.7 exhibits these groups of achievers with their mean scores in the mini-projects. It is apparent from table 7.7 that achiever pupils, in general, tend to be divergent thinkers and not convergent thinkers as no achiever pupils was found to be convergent. However, the sample of the achievers which emerged in the present study is such a small sample that it does not permit of more useful interpretations on behalf of the achiever pupils' behaviour. Moreover, 7 pupils were categorised as belonging to the field-intermediate group which was omitted earlier from the study.

Table 7.7

The mean scores of the achievers with their various learning styles in the mini-projects

Various Groups of Achievers N = 11	F. D. & DIV. N = 1	F. D. & CON. N = 0	F. IND. & DIV. N = 3	F. IND. & CON. N = 0	F. INT.* & DIV. or CON.. N = 7
Mean Scores in the Mini-Projects	13.00	-	11.00	-	Ignored

* Field-intermediate pupils (either convergent or divergent) who were omitted from the study.

7.6.2 The Study of the Conscientious Pupils Group

The same procedure which was used in studying the achievers group was repeated for the conscientious pupils group attempting to understand the influence of various learning styles on the performance of such pupils in the mini-projects.

Table 7.8 has shown how the conscientious pupils who have various other learning styles achieved in mini-projects. The field-independent/divergent conscientious pupils appeared to be the best group of conscientious pupils in performing the mini-projects. On the other hand, the field-dependent/convergent conscientious pupils seemed to be the worst group of conscientious pupils in performing the mini-projects. The field-independent/convergent and the field-dependent/divergent conscientious pupils came in between these two groups in the second and third place successively.

Table 7.8

The mean scores of the conscientious pupils with their various learning styles in the mini-projects

Various Groups of Conscientious Pupils N = 78	F. D. & DIV. N = 14	F. D. & CON. N = 20	F. IND. & DIV. N = 12	F. IND. & CON. N = 12	F. INT.* & DIV. or CON. N = 20
Mean Scores in the Mini-Projects	7.96	6.48	10.25	9.50	Ignored

* Field-intermediate pupils (either convergent or divergent) who were omitted from the study.

7.6.3 The Study of the Curious Pupils Group

This group of pupils was expected to perform well in the mini-projects as curious pupils are considered to be those pupils most interested in doing practical problem-solving in chemistry particularly when such tasks do not involve rigid instructions and require the creativity of pupils.

The results, as shown in table 7.9, demonstrate that curious pupils performed extremely well in the mini-projects. Their mean scores ranged between 8.6 to 11.35 which are considered to be high mean scores and high achievements compared to their colleagues in their achievement in practical problem-solving in chemistry.

Table 7.9

The mean scores of the curious pupils with their various learning styles in the mini-projects

Various Groups of Curious Pupils N = 32	F. D. & DIV. N = 2	F. D. & CON. N = 4	F. IND. & DIV. N = 10	F. IND. & CON. N = 3	F. INT.* & DIV. or CON.. N = 13
Mean Scores in the Mini-Projects	**10.50**	**8.62**	**11.35**	**10.80**	Ignored

* Field-intermediate pupils (either convergent or divergent) who were omitted from the study.

It is believed from such results that curious pupils are always have the potential for high attainments in mini-projects. This could be due to their thinking styles which are more likely to be the divergent and field-independent thinking styles. The curiosity of these pupils may assist them in achieving quite well in tasks requiring creative thinking abilities such as in doing the mini-projects.

7.6.4 The Study of the Social Pupils Group

The same procedure which has been applied on the previous motivational groups was applied to the social motivational group. The pupils were divided into five categories to find out which category achieved best and to determine which characteristics would emerge to describe this pattern in motivation.

Table 7.10 displays the mean scores of the social pupil categories. The results demonstrate that the social pupils who are field-independent/divergent obtained the highest mean score compared to other categories of the social pupils. On the other hand, social pupils who are field-dependent/convergent obtained the lowest mean score of the social pupils.

Table 7.10

The mean scores of the social pupils with their various learning styles in the mini-projects

Various Groups of Curious Pupils N = 57	F. D. & DIV. N = 7	F. D. & CON. N = 9	F. IND. & DIV. N = 17	F. IND. & CON. N = 10	F. INT.* & DIV. or CON.. N = 14
Mean Scores in the Mini-Projects	8.28	7.38	9.44	9.00	Ignored

* Field-intermediate pupils (either convergent or divergent) who were omitted from the study.

The social pupils who are field-independent/convergent came in the third place in achievement, while the social pupils who are field-dependent/convergent came in the last place as they obtained the lowest mean score in mini-projects.

7.6.5 <u>The Study of the Field-Dependent/Divergent Pupils Group</u>

The results which have been obtained from section 7.6.1/2/3/4 were re-arranged in a new way as shown in table 7.11. In such a table, the horizontal rows represent the four motivational patterns of pupils which have been taken into consideration earlier in this section. The vertical columns represent four other groups of pupils. These are; (i) the field-dependent/divergent (ii) the field-dependent/convergent (iii) the field-independent/divergent (iv) and the field-independent/convergent pupils.

It emerges, as table 7.11 clearly shows, that field-dependent/divergent pupils who are recognised as belonging to the achiever motivational pattern obtained the highest mean score over the other motivational patterns of pupils in this group of pupils (with a recognition that only one pupil found in this group was an achiever). The second best performance or achievement which occurred in this group appeared to be from the pupils who were recognised as belonging to the curious motivational pattern.

Table 7.11

The whole picture of the performance of various groups of pupils in the mini-projects

Various Groups of Pupils Total = 124 *	F. D. & DIV.	F. D. & CON.	F. IND. & DIV.	F. IND. & CON.
Mean Scores of Achiever Pupils in Mini-Projects	13.00 N = 1	- N = 0	11.00 N = 3	- N = 0
Mean Scores of Consc. Pupils in Mini-Projects	7.96 N = 14	6.48 N = 20	10.24 N = 12	9.50 N = 12
Mean Scores of Curious Pupils in Mini-Projects	10.50 N = 2	8.62 N = 4	11.35 N = 10	10.8 N = 3
Mean Scores of Social Pupils in Mini-Projects	8.28 N = 7	7.38 N = 9	9.44 N = 17	9.00 N = 10

* 54 Pupils were ignored from the study as they tended to be field-intermediate pupils.

The third and the lowest mean scores in this group (field-dependent/divergent pupils) obtained from pupils who were recognised as belonging to the social and the conscientious motivational patterns successively. Figure 7.4 is drawn in order to show such differences appeared in the mean scores of field-dependent/divergent pupils according to their motivational patterns.

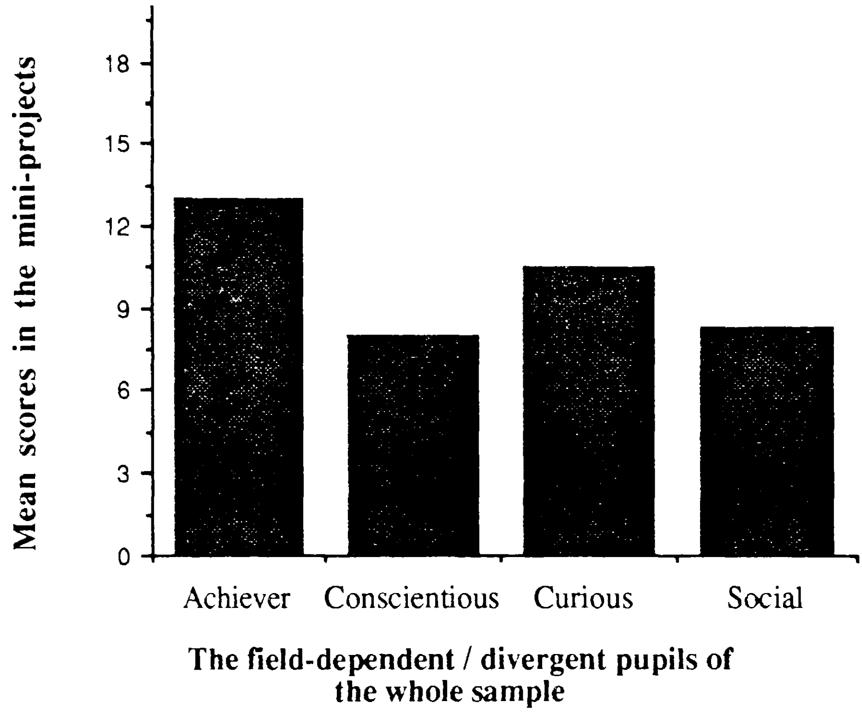


Figure 7.4 The attainments of field-dependent/divergent pupils in mini-projects in accordance with their motivational patterns.

7.6.6 <u>The Study of the Field-Dependent/Convergent Pupils Group</u>

The second column which has been studied vertically is the column which comprises of the field-dependent/convergent pupils. The achiever pupils of this group could not show a field-dependent/convergent learning style in thinking as no achiever pupil behaved as field-dependent/convergent. This could be because either (i) such pupils may not be likely to have such a way of thinking (ii) or this may have happened simply as a fluke.

Nevertheless, the curious pupils of this group appeared to be the best in performance in the mini-projects. Following the curious pupils in performance were the social pupils, while the conscientious pupils appeared to be at the bottom of the list of groups as they obtained the lowest mean score in this group of pupils. The various levels of performance in mini-projects are shown in figure 7.5.

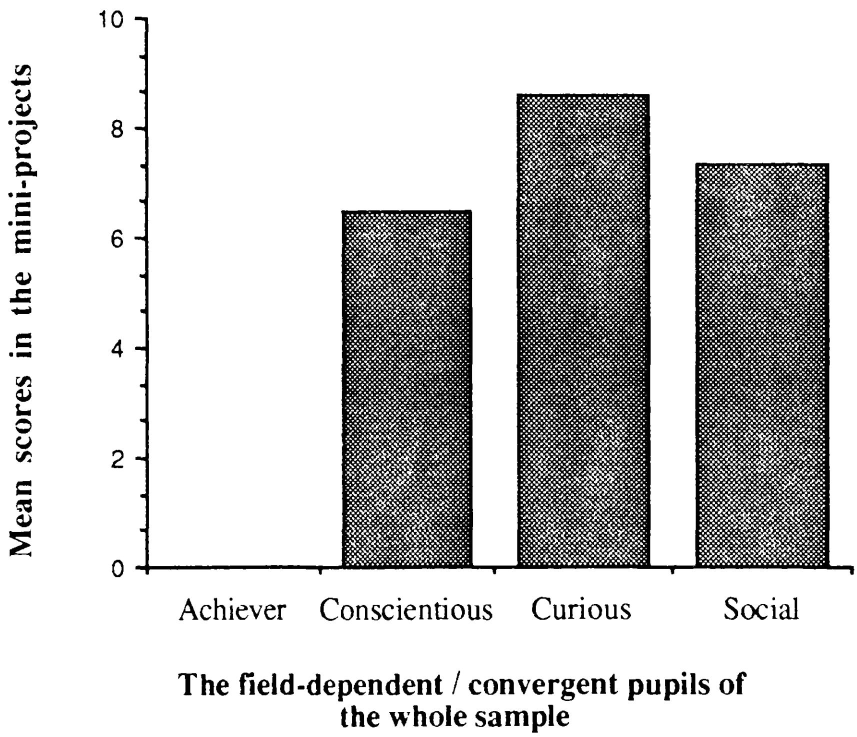


Figure 7.5 The attainments of field-dependent/convergent pupils in mini-projects in accordance with their motivational patterns.

The general performance of this group (field-dependent/convergent pupils) seems to be below the average. These pupils are believed to have difficulties in performing practical problem-solving in chemistry. It could be that such pupils require special care in learning skills involved in the problem-solving matters, and they may need more training and more stimulation than others in order to boost their creativity.

7.6.7 The Study of the Field-Independent/Divergent Pupils Group

In general, the attainments of the field-independent/divergent pupils emerged as above the average. These pupils may be the best in performing practical problem-solving in chemistry. The highest performance of this group of pupils in mini-projects is due to their learning thinking styles. Figure 7.6 displays the achievements of these pupils in mini-projects.

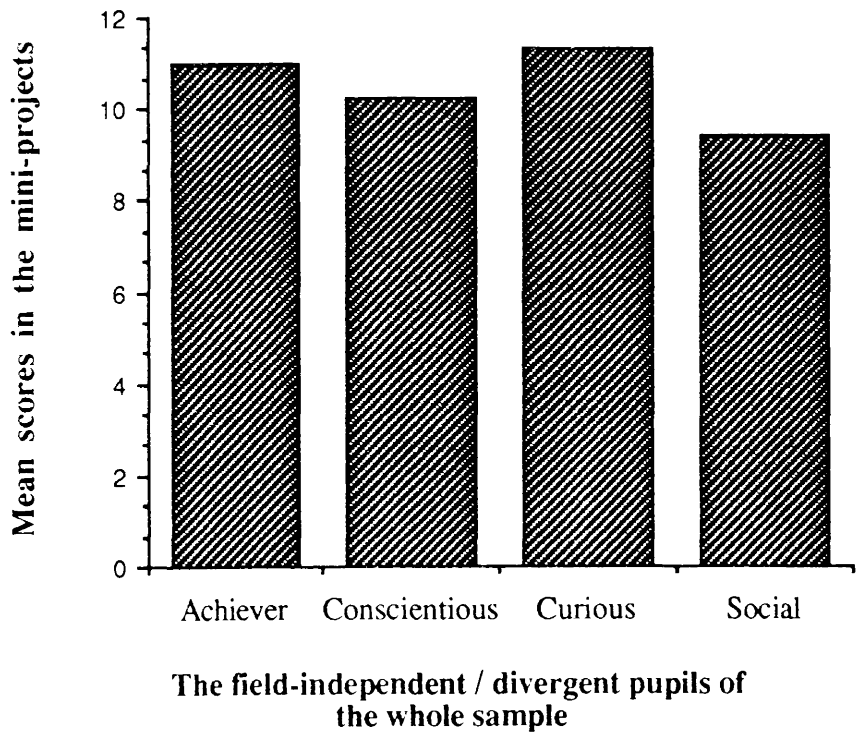


Figure 7.6 The attainments of field-independent/divergent pupils in mini-projects in accordance with their motivational patterns.

However, the curious pupils of this group came in the first place in the competition for the highest mean score. The achiever followed the curious pupils in obtaining the second highest mean score in the group. The third place was occupied by the conscientious pupils, while the last one was taken by the social pupils.

7.6.8 The Study of the Field-Independent/Convergent Pupils Group

In this group, the achiever pupils failed again to appear as field-independent/convergent pupils. This could be interpreted as either happening by chance, or because the achiever pupils who are field-independent tend to think in a divergent rather than a convergent way.

Nevertheless, the curious pupils achieved in the first place, the conscientious pupils followed in the second place, while the social pupils came in the last place. Figure 7.7 displays the achievements of this group of pupils in the mini-projects.

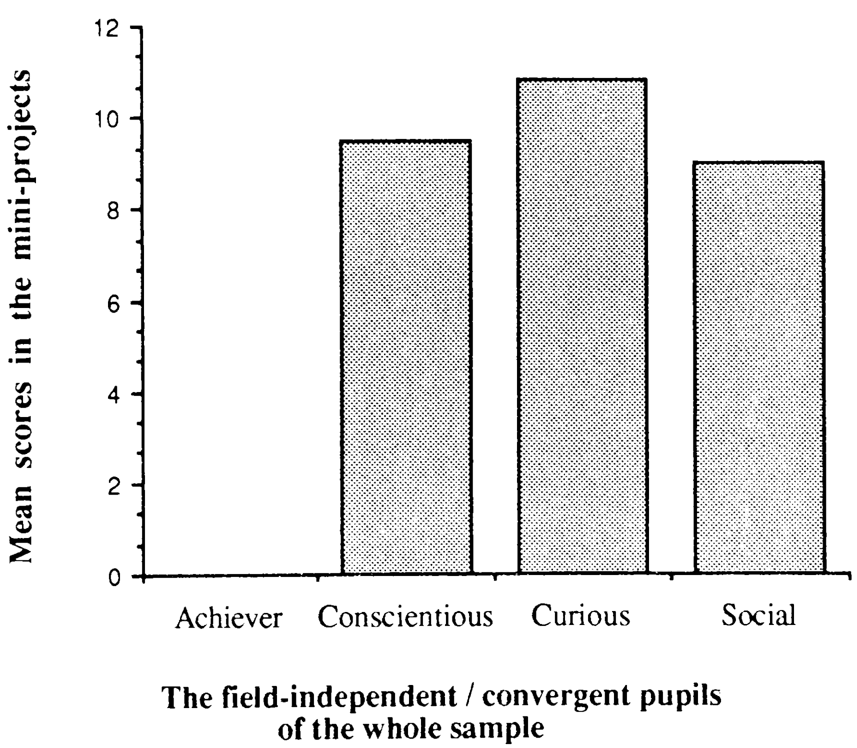
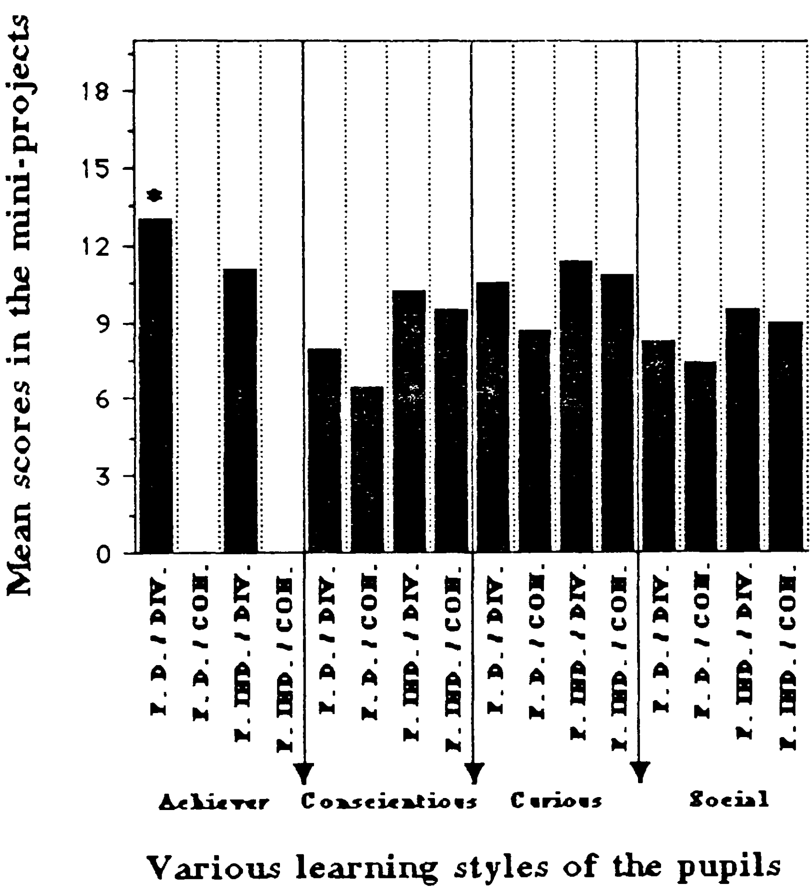


Figure 7.7 The attainments of field-independent/convergent pupils in mini-projects in accordance with their motivational patterns.

7.7 A Resumé of Data Gathered for the Mini-Projects

Until this section of the present research, the researcher has dealt with individual groups of pupils which were obtained from various horizontal and vertical axes set out in table 7.11. The purpose of this was to study the effectiveness of the different learning styles of pupils on their performance in the mini-projects. The results obtained from table 7.11 were drawn in two different ways as shown in figure 7.8 and 7.9. It is to facilitate the understanding of the combined picture which would emerge from the present research.



* This group has been neglected from the research as comprises of one pupil only.

Figure 7.8 The combined picture of the attainments of various groups of pupils (various learning styles) in the mini-projects.

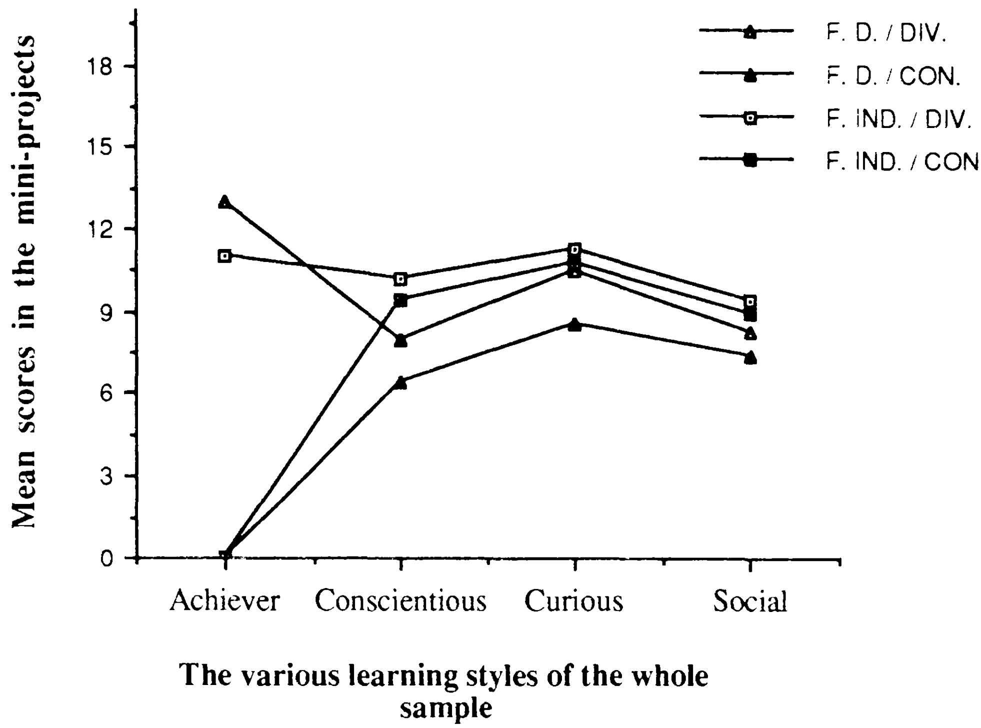


Figure 7.9 The combined picture of the attainments of various groups of pupils (various learning styles) in the mini-projects.

The time now is come to study, in a comparative way, the influence of such various learning styles on the pupils' attainments in mini-projects. In other words, it is to take into consideration the meaningful interactions which surround all the axes (the horizontal and vertical axes with their boxes) involved in table 7.11 versus each other, on one hand, and versus the mean scores in mini-projects, on the other hand.

1 - Studying the horizontal and vertical strips in table 7.11 to find out the best group (a single box) in achievement, it emerged that the best achievement which has been obtained in performing the mini-projects comes from the field-dependent/divergent and achiever group of pupils (mean score = 13) which, in fact, failed to contain more than one pupil. Therefore, this group cannot be significantly considered and will be neglected from the study. Thus, the best

group of pupils in achieving of the mini-projects is considered to be the field-independent/divergent and curious group which obtained a mean score of 11.35. The second group in the best achievement in the mini-projects is the field-independent/divergent and achiever group of pupils, these pupils obtained a mean score of 11.00. The field-independent/convergent and curious group of pupils comes at the third place. On the other hand, the worst group which achieved the lowest mean score in the mini-projects appears to be the field-dependent/convergent and conscientious group of pupils.

2 - The other way of looking at the data obtained from table 7.11 is by studying the achievements of the various groups of pupils in columns and rows (vertically and horizontally). This would be achieved if the mean scores of pupils were averaged in each vertical and horizontal column to provide the research with the actual picture of each group's attainment and in columns. Having done that, the picture of the attainments in mini-projects (excluding the field-intermediate pupils as well as neglecting the achiever mean scores horizontally as some their boxes contain no pupils) appeared to be as follows:

(i) The highest averaged mean scores obtained from the curious pupils (a third row) with an average of 11.00.

(ii) The second highest averaged mean scores obtained from the field-independent/divergent pupils (a third column) with an average of 10.23.

(iii) The lowest averaged mean scores obtained from the conscientious pupils (a second horizontal column) with an average of 8.24. However, it was found that the averaged mean scores of the conscientious and social pupils along the second and the fourth columns were quite similar (the averaged mean scores of the social pupils was 8.71).

From table 7.11 and in general, the achiever pupils have never been shown to be field-dependent/convergent or field-independent/convergent thinkers (as no achiever pupils were obtained in these groups). Instead, they appeared to be divergent rather than convergent thinking pupils.

The curious pupils seemed to be the best pupils in performing the mini-projects. Moreover, the field-independent/divergent and curious pupils seemed to be the best pupils in the sample in achieving high scores in mini-projects.

The social and the conscientious pupils, as stated above, performed similarly in mini-projects. However, the field-dependent/divergent and the field-dependent/convergent pupils of the social group achieved better than their colleagues with the same learning styles and who belong to the conscientious group. The picture is reversed when the reader looks at the field-independent/divergent-convergent of both groups of pupils. The field-independent/divergent and the field-independent/convergent pupils of the conscientious group achieved better than the field-independent/divergent and the field-independent/convergent pupils of the social group.

For the conscientious pupils, being field-independent will qualify a pupil as a high achiever in mini-projects over his/her group (the conscientious group) and over the social group. Being field-independent/divergent will more qualify a pupil for high achievement in mini-projects over the same mentioned groups of pupils.

For social pupils, being field-independent/divergent pupils will qualify a pupil for the best score in mini-projects over his/her group (the social group) and over the field-dependent/divergent-convergent pupils of the conscientious group of pupils. At the same time, being a social pupil with a field-dependent/divergent style of thinking may qualify a pupil for the best score in mini-projects over his/her conscientious colleague of a field-dependent/divergent style of thinking. The same rule would be applied for the social field-dependent/convergent pupil over the conscientious field-dependent/convergent pupil.

A hypothesis was set out in chapter five (**hypothesis 5**) concerning the attainments of field-independent pupils who are divergent in the mini-projects. This hypothesis has predicted that these pupils (field-independent and divergent) who are either achiever or curious pupils would achieve better than field-independent pupils who are convergent and who belong to any motivational pattern. The results emerging from table 7.11 support such a hypothesis. Such groups of field-independent pupils obtained higher mean scores than the rest of field-independent pupils.

7.8 A Model Emerged from the Research which Systematises the Influence of Various Learning Styles on the Performance of Pupils in the Mini-Projects

Being aware of the achievements of various groups of pupils in the mini-projects, the influence of the psychological factors used in the present study may become understandable.

A number of deductions have arisen from the overall results about the priority and the degree of effectiveness of such psychological factors on the pupils' achievement and performance in practical problem-solving in chemistry.

The first deduction is that the field-dependent/field-independent learning styles may be the most important styles of thinking in performing the mini-projects. Being field-independent might allow a pupil to perform in a superior way while being field-dependent tends to depress the performance of a pupil in the mini-projects.

The second deduction is that the motivational patterns of pupils may effect the pupils' performance in mini-projects. It is believed, from the data which emerged in table 7.11, that such effectiveness comes in second place after the effectiveness of field-dependence/field-independence on pupils' performances.

The third deduction is that the divergent/convergent thinking styles may be considered in the third place in importance. It seems that pupils with divergent thinking style are more able than their colleagues (of convergent thinking style) in achieving high scores in the mini-projects.

In brief, it is found in this study and from the mean scores of pupils with various learning styles (table 7.11) that field-independence/field-dependence are more effective than the motivation and divergence/convergence in performing the mini-projects. The priority thus is given in the first place to the field-independent/field-dependent learning style in performing practical problem-solving in chemistry.

Therefore, the predictive influence of the field-independent factor in performing the mini-projects, as exhibited in table 7.12, is considered to be a positive influence (arrow to the right) which enhances the achievement, while it is a negative influence (arrow to the left) for the field-dependent factor which lessens the achievement.

For the motivation factor, the predictive influence of the achiever pattern in performing the mini-projects is considered to be a positive influence which enhances the achievement. It is a positive influence again (arrow to the right) with the curious pattern leading to an enhancement in achievement. Whilst, a negative influence (arrow to the left) which may lessen the achievement in performing the mini-projects would be expected of the conscientious and the social patterns.

For the convergent/divergent thinking styles, a positive influence (arrow to the right) would be expected of the divergent style which enhances the achievement, while it is a negative influence (arrow to the left) would be expected of the convergent style in thinking which lessens the achievement in mini-projects.

1- Building on this, the achievements of many groups, as shown in table 7.12, could be now justified. For example, having three positive arrows (to the right) would enhance the pupil's achievement to its best level (as occurred with the field-independent/divergent and achiever pupils who obtained a mean score of 11.00 or field-independent/divergent and curious pupils who obtained a mean score of 11.35), while having three negative arrows (to the left) would lessen the pupil's achievement to its worst level (as occurred with the field-dependent/convergent and conscientious pupils who obtained a mean score of 6.48 or field-dependent/convergent and social pupils who obtained a mean score of 7.38).

2 - Furthermore, the achievement in mini-projects can be enhanced by two positive arrows (to the right), but would be diminished if a negative arrow (to the left) existed. For example, the achievements of field-independent/divergent and conscientious pupils who obtained a mean score of 10.24 or field-independent/divergent and social pupils who obtained a mean score of 9.44 were diminished as a negative arrow were existed in each group (because of their motivational patterns). Another example of this category is represented by the field-independent/convergent and curious pupils who obtained a mean score of 10.8 or field-dependent/divergent and curious groups of pupils who obtained a mean score of 10.50 whose their achievements were diminished as a negative arrow (to the left) existed (the negative arrow was found because of the convergent learning style of the first group and the field-dependent learning style of the second group of pupils).

Table 7.12

The model of the present study which emerged from the whole picture of the achievements of various groups of pupils in the mini-projects

Various Groups of Pupils Total = 124	F. D. & DIV. ← →	F. D. & CON. ← ←	F. IND. & DIV. → →	F. IND. & CON. → ←
Mean Scores of Achiever Pupils in Mini-Projects →	13.00 → ← →	- → ← ←	11.00 → → →	- → → ←
Mean Scores of Consc. Pupils in Mini-Projects ←	7.96 ← ← →	6.48 ← ← ←	10.24 ← → →	9.50 ← → ←
Mean Scores of Curious Pupils in Mini-Projects →	10.50 → ← →	8.62 → ← ←	11.35 → → →	10.8 → → ←
Mean Scores of Social Pupils in Mini-Projects ←	8.28 ← ← →	7.38 ← ← ←	9.44 ← → →	9.00 ← → ←

→ To the right (positive) means to enhance the achievement in mini-projects.

← To the left (negative) means to lessen the achievement in mini-projects.

Note about table 7.12: In the boxes which contain three arrows, the upper arrow represents the influence of the motivational patterns, the middle arrow represents the influence of the field-dependent/field-independent learning styles, while the lower arrow represents the influence of the convergent/divergent learning styles on the achievements of pupils in the mini-projects.

3- The final category in table 7.12 is the one which comprises of two negative arrows (to the left) and a positive arrow (to the right). The field-independent/convergent and conscientious pupils who obtained a mean score of 9.50 or the field-independent and social groups of pupils who obtained a mean score of 9.00 are examples of this category. Both groups obtained two negative arrows because of their field-dependent learning style and their motivational patterns which diminished their achievements in mini-projects. However, such groups of pupils (in this category) appeared to be good survivors compared to others since they obtained the highest mean scores over their colleagues in the same category. This is due to their effective field-independent learning style. Other examples of the same category are the field-dependent/divergent and conscientious pupils who obtained a mean score of 7.96 or the field-dependent/divergent and social pupils who obtained a mean score of 8.28 or the field-dependent/convergent and curious groups of pupils who obtained a mean score of 8.62. The first and second groups of pupils obtained a positive arrow because of their divergent learning style, while the third group of pupils obtained a positive arrow because of their curious motivational pattern.

Finally, it is prudent to remind the reader that being field-independent or an achiever or curious or divergent would give the pupil the best chance in performing mini-projects. Furthermore, the pupil would be expected to achieve in a superior way in mini-projects if his/her thinking style is that of field-independent/divergent/achiever or curious styles of thinking.

7.9 Summary

The present chapter has clarified the picture of the influence of some psychological factors upon each other and upon the skill of practical problem-solving in chemistry (the mini-projects).

It is found that a statistically positive correlation is obtained between the pupils' scores in the field-dependent/field-independent test and their scores in mini-projects. Also, the same statistical positive correlation found between the pupils' scores in the convergent/divergent tests and their scores in the mini-projects. Therefore, field-independent and divergent pupils are more able than field-dependent and convergent pupils in performing mini-projects, because field-independent and divergent pupils are more capable of dealing with problems which are surrounded by 'noise', they are also more capable of devising methods leading to the solutions of such problems.

It is also found in this chapter, concerning the motivation factor, that the curious pattern is the most likely pattern for the highest scores in the mini-projects (neglecting the performance of the achiever pattern as a very few pupils were found being achievers in the research). The conscientious and the social motivational patterns are followed the curious pupils in the competition, they are almost even in scores in performing the mini-projects. The study has paid attention to the curious pupils since these pupils (no matter how they have been recognised in their schools concerning their level of achievement in chemistry whether it is standard or above or below the standard level) achieved well in the mini-projects. It could be that their curiosity and creativity, according to their particular motivational pattern, allowed them to achieve a high performance in mini-projects.

Putting all the psychological factors in the study together versus the achievements of pupils obtained in the mini-projects confirms that the field-independent/divergent pupil who is belonging to the curious motivational group achieved the best mean score (11.35) in the mini-projects (neglecting the achievement of the unique field-dependent/divergent pupil who is an achiever). Whilst, the worst pupils in performing the mini-projects emerged as the field-dependent/convergent pupils who belong to the conscientious motivational group (mean score = 6.48).

Moreover, the average of the mean scores of various groups of pupils (vertical and horizontal columns) showed that the superior group in performing the mini-projects is the curious motivational group (the average of the mean scores is 11.00). Followed this group in the best achievement is the field-independent/divergent group (the average of the mean scores is 10.23). Whilst the worst group in performing the mini-projects is the conscientious motivational group (the average of the mean scores is 8.24).

The field-dependent/field-independent psychological factors appeared to influence the pupils' achievements in the mini-projects in a significant way. The motivational patterns of pupils would influence the pupils' achievements in the mini-projects in as significant a way as the convergent/divergent thinking styles of the pupils.

The present study has created a predictive model for the influence of various learning styles on the performance and achievement of pupils in practical problem-solving in chemistry. In this model, the field-independent and divergent learning styles as well as the curious or achiever motivational patterns are believed to enhance the pupils' achievements in the mini-projects, while the field-dependent and convergent thinking styles as well as the conscientious and social motivational patterns are believed to lessen the pupils' achievements in the mini-projects.

CHAPTER EIGHT

CONCLUSIONS AND DISCUSSION

8.1 The Findings of the Present Research

The immediate section of this research is devoted to an analysis of some learning styles of pupils and their influence on the field of practical problem-solving in chemistry. It is a fact that teachers get confused, on occasions, when they observe some pupils, who are supposed to be poor at science, performing and achieving well in some forms of practical science such as those which require investigations and explorations.

In his previous research[1], the researcher explored the effectiveness of some psychological factors (the working space capacity, field-dependence/field-independence and intelligence) on the performance of learners in conventional chemistry examinations. In the present research however new psychological factors were explored and examined to understand their influence on the performance of learners in practical problem-solving in chemistry, particularly, on the learners who may be described as average or below average in theoretical science and who may surprisingly achieve well in some sorts of practical science. Such research could be considered as complementary to the previous research, and further as a completion of the latter, in studying and predicting the learners' performances, who are varied in their learning styles, in theoretical as well as in practical chemistry.

The aspects which have emerged in the present study could be summarised in the following conclusions:

(a) In addition to the pupils' holding/thinking space, field-dependence/field-independence (based upon the information processing model) and intelligence, there are other psychological factors which may influence the learning of pupils in science. For example, the convergent/divergent thinking styles and motivational patterns may have a great influence on the performances of pupils in science, particularly, when tasks require explorations and creative ideas to be used for their solutions.

(b) Three factors have been identified and studied in this thesis with their influence on the pupils performing creative and stimulating practical problem-solving in chemistry (the mini-projects).

1 - The field-dependent/field-independent styles of thinking. Field-dependent pupils would find difficulty in separating an item from its context and would accept the context as it is. Field-independent pupils would readily break up an organised input of information and easily separate an item from its context. Finally, the field-intermediate pupils would come in between these groups of pupils (omitted from the study).

2 - The convergent/divergent styles of thinking which may again divide the pupils into convergent thinking pupils who have thought processes which lead them to a narrowing down of a problem to one idea, one given end, and the divergent thinking pupils who think in such a way that ideas may branch out and explode into new shapes and patterns.

3 - The motivational patterns of pupils allow for a further division of pupils into the achiever, the conscientious, the curious, and the social pupils respectively.

(c) The research has chosen the mini-projects as a special form of practical problem-solving in chemistry. These projects are considered to be a new element in school chemistry aimed at the stimulation of pupils' motivational preferences towards creativity. Pupils themselves take control of experiments after designing their workable methods. This could be a new mode of practice in problem-solving chemistry which should be encouraged in school science.

(**d**) The researcher has used several tests in order to measure the pupils' learning styles. These tests have been designed at the Centre for Science Education in Glasgow University. Moreover, he has designed a method for assessment of the mini-projects, solely for the purpose of research, since no method so far has been set up for assessing of the mini-projects for examination purposes.

(**e**) Working towards possible correlations between the various psychological factors themselves which have been employed in the study, it was found that the field-dependent/field-independent psychological factor correlated positively with the convergent/divergent ways of thinking. In other words, a field-independent pupil may be expected to be a divergent thinker, while a field-dependent pupil may be expected to be a convergent thinker. Motivational patterns were found to overlap with each other, and with other psychological factors such as field-dependence, field-independence, convergence, and divergence. The highest overlapping pictures obtained between the motivational patterns was found to be between the conscientious and the social patterns (their performances and achievements in the mini-projects were similar). On the other hand, the overlaps between all the three psychological factors involved in the study emerged in the following ways; (i) it is more likely to be between the field-independent, divergent, and the achiever or curious learning styles (ii) and it is more likely to be between the field-dependent, convergent, and the conscientious or social learning styles. However, more than one overlapping motivational pattern is quite possible with both the groups (i,ii).

(f) In the achievements for the highest mean scores in the mini-projects; firstly, the field-independent pupils obtained higher mean scores than the field-dependent pupils. Secondly, the divergent pupils also obtained higher mean scores than the convergent pupils. Finally, the achiever pupils obtained the highest mean scores compared to their colleagues with other motivational patterns. The curious pupils achieved well too and followed the curious in the competition for the best achievement. The conscientious and social pupils achieved similarly in the mini-projects. They obtained almost the same mean scores. This could be due to their motivational patterns which significantly overlapped between them as was seen in the present study.

(g) Five hypotheses were proposed and then tested later in the present study related to the influence of various learning styles on the pupils' achievements in mini-projects.

1 - The verification of *hypothesis (1)*: It was found that field-dependent/divergent pupils could achieve better than field-dependent/convergent pupils in the mini-projects.

2 - The verification of *hypothesis (2)*: It was also found that the field-independent/divergent pupils who are achiever or curious obtained higher scores in mini-projects than the field-independent/convergent pupils who belong to any motivational pattern.

3 - The verification of *hypothesis (3)*: In general, field-independent/divergent pupils are more able than field-independent/convergent pupils in performing the mini-projects and in obtaining the highest mean scores.

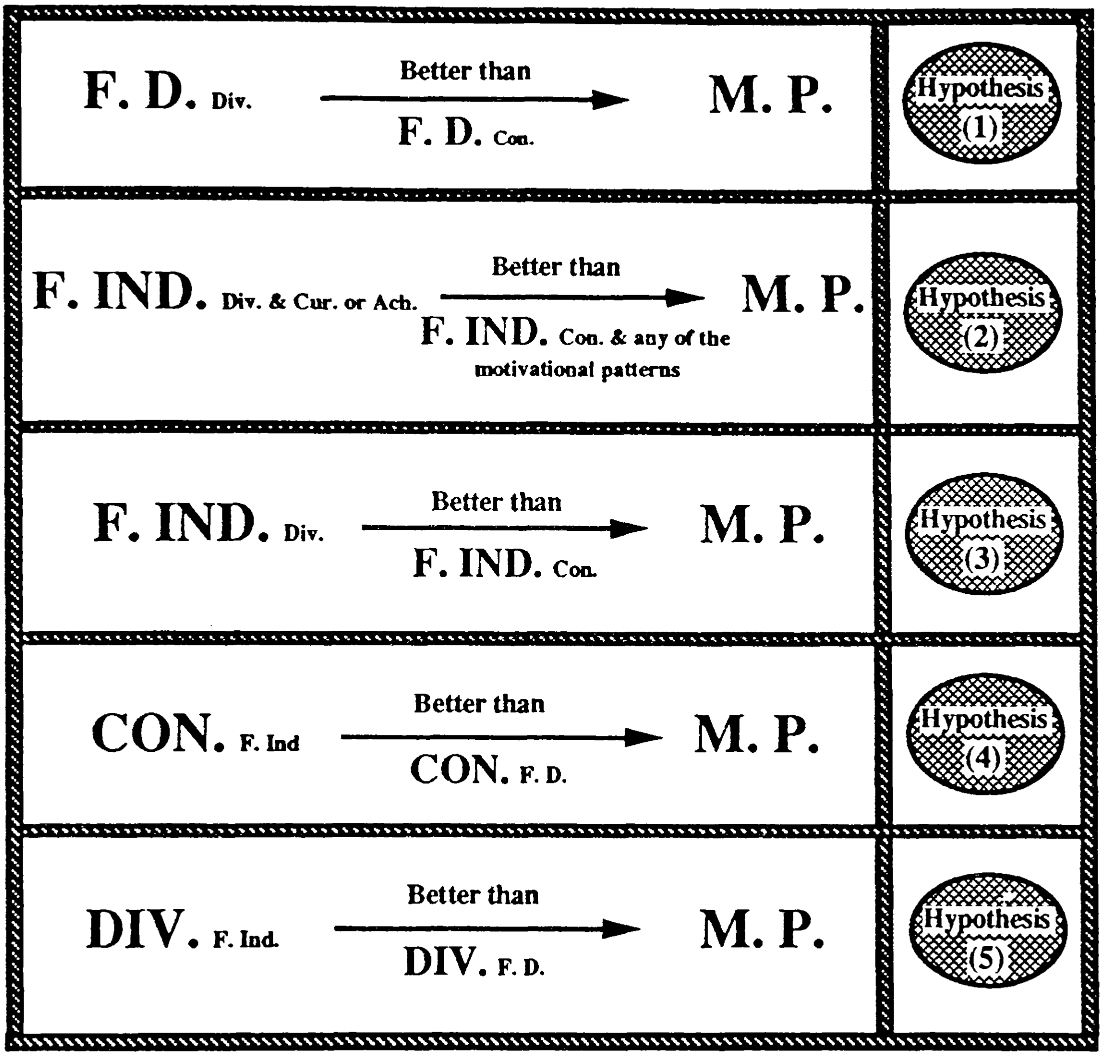
4 - The verification of *hypothesis (4)*: The convergent pupils who are field-independent were found to be more able than their convergent colleagues

who are field-dependent pupils in achievements in the mini-projects.

5 - The verification of *hypothesis (5)*: It was also found that the divergent pupils who are field-independent could achieve better than the divergent pupils in the mini-projects who are field-dependent. These hypotheses are displayed in figure 8.1.

(**h**) The pupils' field-dependence, field-independence, convergence, divergence and motivation are very important and may play a vital role in problem-solving procedures, particularly, in tasks which have discovery features in their nature and which demand peculiar abilities of pupils. However, it was found that the field-dependent/field-independent thinking styles are more effective than the other two factors (the convergence/divergence and motivation) in tackling such problems. The motivational preferences of pupils featured as second in importance according to the results which emerged in the thesis. The convergent/divergent thinking styles appeared to be in third place.

(**i**) If the groups of pupils (each group being measured according to all the psychological factors involved in the study) were arrayed in a list in accordance with their achievements in the mini-projects, the <u>field-independent/divergent/curious</u> pupils group would be listed in first place. The <u>field-independent/divergent/achiever</u> pupils group would be located in the second one, while the <u>field-independent/convergent/curious</u> pupils group would capture the third position. At the other end of such a list, the <u>field-dependent/convergent/conscientious</u> pupils group would capture the bottom position in their achievement in the mini-projects (although to make such allocations the field-dependent/divergent/achiever pupils should be neglected as such a grouping comprises of only one pupil).



F.D. Field-dependent pupils

F.IND. Field-independent Pupils

Cur. Curious pupils

CON. Convergent pupils

DIV. Divergent pupils

Ach. Achiever pupils

M. P. Mini-projects

Figure 8.1 The deductions from the present study compared with the original hypotheses.

(j) Another array may be visualised from the research. If the four mean scores in each horizontal and vertical column of the research's various groups of pupils (as shown in table 7.11 or 7.12 in chapter seven) were averaged, the highest attainments would be obtained from the curious pupils in the third row (average mean scores of the curious' groups of pupils is 11.00) and would be followed by the attainments of the field-independent/divergent pupils in the third column (average mean scores of the field-independent/divergent groups of pupils is 10.23) . Whilst, the lowest attainments would be obtained from the conscientious pupils in the second row (average mean scores of the curious' groups of pupils is 8.24). In fact, the achiever pupils with their various groups may be expected to achieve a superior mean score but no one of this group was found to be field-dependent/convergent or field-independent/convergent which has complicated the average workings of this group. However, it is fair to mention that this group is able to achieve very well in the mini-projects.

(k) A model emerged from the present study (table 7.12) concerning the expected performance of pupils with their various learning styles in practical problem solving in chemistry. It seems that some of the psychological factors used in the study would enhance the achievement in the mini-projects, while others would lessen it. The field-independent and divergent learning styles as well as being an achiever or curious would all be considered capable of enhancing the achievement in mini-projects. On the contrary, the field-dependent and convergent learning styles as well as being a conscientious or social would all be considered capable of diminishing the achievement in mini-projects. Therefore, the model has suggested positive arrows (to the right) for having positive factors (enhancing factors) and negative arrows (to the left) for having negative factors (diminishing factors). When these arrows are inserted in the pupils' achievement table (table 7.11), they may justify the pupils' various levels in achievements in the mini-projects. In general, three positive arrows would be expected for the best achievement such as the one obtained from the field-independent/divergent/curious pupils (the highest mean score), while three negative arrows would be expected for the worst achievement in mini-projects such as the one obtained from the field-dependent/convergent/conscientious pupils (the lowest mean score).

8.2 Some Predictions from the Present Research's Findings

The research has used practical problem-solving in chemistry (mini-projects) as the chemistry body in the study. However, it could be very useful for this study and for general educational purposes to study the performances and achievements of the pupils in this sample (with their various learning styles as dealt with during the period of the study) in theoretical chemistry (conventional chemistry examinations). This may provide teachers and educators with a precise picture of the effectiveness of various learning styles on the pupils work in the classroom as well as the laboratory.

A number of predictions concerning the researcher's sample of pupils are therefore possible concerning their expected performances in the conventional chemistry examinations, as follows:

(a) The field-independent, divergent and the achiever or curious pupils are expected to achieve better than the field-dependent, convergent and the conscientious or social pupils in the conventional chemistry examinations. This is due, of course, to the pupils' learning attributes and as prescribed in the research.

(b) It was found in hypothesis one that field-dependent/divergent pupils achieved better than field-dependent/convergent pupils in the mini-projects. Thus, the research anticipates that field-dependent/divergent pupils could still achieve better than field-dependent/convergent pupils in the conventional chemistry examinations. Their divergent thinking style may qualify them for high scores in the chemistry examinations, specifically, if such examinations are open-ended or demanding open imagination and thinking (the picture could be reversed in other particular subjects, for example, mathematics).

(c) As anticipated in hypothesis three, the field-independent/divergent are better than the field-independent/convergent pupils in the mini-projects. The research anticipated that these pupils in both groups would achieve similarly in conventional chemistry examinations because their field-independent thinking style could be more effective than the convergent/divergent thinking styles in routine examinations (without creativity) which more often require recall processes.

(d) In hypothesis four, the convergent pupils who are field-independent achieved better in the mini-projects than the convergent pupils who are field-dependent. The present study predicts that the same picture may be obtained again in the conventional chemistry examination. This is because of the high influence of the field-independent thinking style on the performance of the convergent pupils.

(e) The divergent pupils who are field-independent achieved better than the divergent pupils who are field-dependent (hypothesis five) in the mini-projects. It could be expected that the same thing would occur in performing conventional chemistry examinations, this being due to the same reason mentioned in (d).

8.3 Suggestions for Further Research

In any research field, a researcher may find, at the end of the day, many questions have arisen unexpectedly from the research. A discussion of such questions and advice could be prudent for education purposes:

(a) As stated in section 8.2, another study may be extremely useful in order to comprehend the influence of the various learning styles which have been involved in the present research on the performance of pupils in conventional chemistry examinations. The results of such findings could have important implications for classroom procedure, involve a reworking of teaching methods and instructional procedures in chemistry.

(b) Further research may well be pertinent on the involvement of another psychological factor - the working memory capacity factor. This could lead a researcher to more findings about any selected sample for a study.

(c) It could be very interesting to follow the sample of the present research in schools to see their performance and progress in more advanced chemistry as well as in other subject areas.

(d) Could it be useful to apply the same work in other science subjects such as physics or biology?

(e) Could it be that there are other psychological factors involved in performing creative sorts of practical problem-solving in chemistry?

(f) Ultimately, the present research has used a creative task in chemistry (Mini-Projects) to show the achievements of various pupils with various thinking styles. It did not use the normal practical chemistry activities which are already found in the school laboratory because such activities are more often teacher-centred rather than pupil-centred. Therefore, a new look at the chemistry practical activities in the school laboratory is essential for a fruitful learning of chemistry.

8.4 The Research's Message for the Educators

Every piece of research in science education ought to deliver a message(s) to educators or teachers from its findings. The present research conveys an educational message to the educators about what to do for better learning processes in the school's laboratory. The research's message concerns not only the laboratory work but may extend to include what to do further for a better curriculum in the secondary schools particularly in Standard Grade Chémistry.

First, a message could be derived from the research on the emphasis for a better practical activity in the laboratory. The present practical work in the school's laboratory involves activities that are 'teacher-directed' and not 'pupil-directed'. In the conventional school laboratory, the pupils are operating on experiments which are directed by the teacher and which may not stimulate the creativity of pupils for the enhancement and promotion of chemistry learning. Moreover, these experiments sometimes have even meaningless objectives for a better learning of chemistry in school.

Thus, a new technique of administering the experiments in the school's laboratory is required to move such experiments from being 'teacher-centred' into being 'pupil-centred'. This, in fact, may lead to a review of the chemistry materials involved in the practical work such as the manuals, lab notes and any other relevant book for the chemistry experiments.

Secondly, another message could be directed to the educators about the necessity for a balanced curriculum in the Standard Grade which would provide learning tasks to fit all of the categories of pupils (the various learning styles studied in the research) and to allow them all to achieve to the best of their ability.

At present, the curriculum provides plenty for the achiever and the conscientious pupils and may even favour the convergent over the divergent.

Therefore, a balanced curriculum in the Standard Grade should provide; (i) "comfortable" converging experiences (ii) "challenging" creative experiences for the divergers (iii) and "social" experiences of discussions.

The present Standard Grade course provides (i) and (iii) but needs (ii) to become balanced and more effective. In other words, a fresh look is needed in the curriculum (chemistry in particular) to construct some sort of "challenging" creative experiences for the divergent thinking pupils and for the curious pupils. The curriculum would then provide learning experiences suitable for all types of pupils.

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