A STUDY OF SOME PSYCHOLOGICAL FACTORS AFFECTING PERFORMANCE IN CHEMISTRY AT SECONDARY AND TERTIARY LEVELS

by

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TO MY FAMILY HERE AND IN IRAQ *****

ABSTRACT

This thesis describes a predictive model for science education based upon information processing theory. It is based upon research conducted by the Science Education Group at Glasgow University. The model predicts to some extent the achievement of learners in conventional science examinations. The present study examines factors which might influence the understanding and performance of learners in chemistry education.

The empirical work of the study was done with 177 Glasgow University students in the session 1986-1987, 283 school pupils at "O" Grade (age 16), and 284 Glasgow University students in the session 1987-1988.

An examination was made of the idea of a limited space in the learner's brain called the holding/thinking space. This area can easily be overloaded by increasing the burden of information on it. Therefore, the learner's performance may decline rapidly as soon as the input information becomes bigger than the size of the learner's space.

Furthermore, other factors have been considered in this thesis such as field dependent/independent cognitive style and 'intelligence' (V. R. Q.) to find their relationship with the model of the information processing hypothesis in science education. Apparent in the results which emerged from this empirical work was that field-dependent learners tend to have a small holding/thinking space which is insufficient to hold both relevant and irrelevant information. The study recommends that teachers should re-organise their materials in a way which would facilitate the separation of relevant from irrelevant material.

The research on 'intelligence' requires further work as the intelligence scores of the selected sample were measured at an age before the holding/thinking space was fully developed. It may be that intelligence test tasks may not exceed the working memory capacity of any learner so our understanding of the information processing model assumes that the intelligence test measures some other factor.

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INTRODUCTION

Information processing theory has been studied by many researchers. The common theme of the theory evolves through the idea of how input information is stored and processed inside the human mind and how a response to this comes into existence.

The investigations which have been conducted in the information processing field have studied in the three types of memory: the sensory-memory; the short-term memory; and the long term memory. The procedure of the acquisition of knowledge relies mainly on the action of these memories.

The work of the new predictive model of the theory depends on the functions and effects of that part of the brain where information is held, organised, shaped, and worked upon before it is stored. This area is designated the holding/thinking space or the X-space. The model of the research elaborates some work which was conducted by Pascual-Leone and his colleagues. The bases of their investigations originated from Piaget's theory. The work of Pascual-Leone and his colleagues is named the new-Piagetian hypothesis.

Chemistry as a science subject must be taught and represented to learners in a way which benefits them. At the tertiary as well as the secondary level of chemistry education, the methods of teaching chemistry and of organising conventional examination questions highlight some defects which require re-examination and re-interpretation in correspondence with learners' limited X-space. The model of the hypothesis explores some strategies in teaching that could be followed to reduce the overloading of the working memory capacity and the misleading of learners, in addition to presenting some techniques which could be employed in chemistry teaching for the same purpose.

Three essential factors come together in this model; mental capacity, the field-dependent/independent cognitive style, and 'intelligence', which can affect the performance of learners in chemistry examinations or during chemistry learning.

It seems prudent to start this research by studying the current literature dealing with information processing theory and by focusing on any part of this which is relevant to the research. Many schools, in addition to the many investigators, were involved with the information processing hypothesis and elaborated it with their various interpretations. It is hoped that the work in this study is presented in a way which is both beneficial and meaningful.

CHAPTER ONE

General review of models for learning (Piagetian, Ausubelian, and New-Piagetian theories)

1.1 Piaget's theory of intellectual development

Because of his early training and work as a biologist, Piaget came to believe that biological acts are acts of adaptation to the physical environment and the organisations of that environment, and therefore intellectual development could be concepualized in the same way. In fact, the concepts of biological development are both a useful and a valid means by which intellectual development can be viewed. In this sense cognitive acts may be seen as acts in response to the organisation of the perceived environment.

Piaget affirms [1] that intellectual and biological activity are both integral to the overall process by which an organism experiences the environment.

Piaget defines the word 'intelligence' [2] in a very specific way. Intelligence is 'the coordination of operations'. An operation reflects a rule, but it is not identical with it.

However, he believes that the child passes through four stages of intellectual growth to achieve the end state which is called adult thought. The first two stages - *the sensory-motor (0-2 years)* and *the pre-operational (2-7years)* are not relevant to our study, because the study is dealing with secondary and tertiary education.

The third stage *-the concrete operations period (7 Years-adolescence)* commences when the formation of classes and series takes place mentally, that is to say, when physical actions become 'internalised' as mental actions or 'operations'.

The egocentricity of the child decreases substantially and reliable co-operation with others replaces it.

In brief, we can say that the child, in the concrete operations stage, is able to solve problems with which he is faced, but his solutions are characteristically in terms of direct experiences.

Beard (1969) states [3] that Piaget may be unduly optimistic in suggesting that children accomplish the concrete operational stage by about the age of eleven as his samples were small and could therefore not represent the majority of children.

The fourth stage - *The formal operations period (12 years-three years later)* coincides approximately with the onset of adolescence [1]. The adolescent becomes able to solve all classes of problems since he develops reasoning and logic, he manipulates ideas not directly related to the real world, and he starts to integrate his new intellectual capacities [4] for explanatory purposes.

Piaget specifies 'co-operation with others' as the first of a series of forms of behaviour which are important for the constitution and development of logic and he believes that formal operations are originated through co-operation with others.

Several differences can be observed between the child and the adolescent. Firstly, the child will be satisfied when he has hit on the correct solution by 'trial and error', that is to say, he does not conceive a general law. Whereas the adolescent will state his hypotheses as general laws which he then tests. Secondly, in terms of expectation, the child tends to see successive instances as separate, unrelated events while, the adolescent sees quickly that several instances of a kind suggest the existence of a law which should hold good in all similar cases. Thirdly, the child thinks that there are no laws with general application yet every event is 'explicable': the impossible can be imagined as a reality. The attitude of the adolescent, on the other hand, is to expect to find general laws which enable him to recognise that an event may be a fortuitous event, for he realises that it may occur in a situation in which no law is operating.

Beard (1969) notes [3] that Piaget does not provide illustrations of the exhaustive and general definitions characteristic of educated adolescents or adults.

Furthermore, Piaget's theory has given insufficient interpretation of intellectual development [5] since it depends on a descriptive structure and therefore, it provides no satisfactory means of gaining predictions from it of structural change.

Piaget emphasises that [6] knowledge does not come to us from the external environment, 'ready-made'. Our minds are neither photographic plates to receive pure impressions (a copy of reality) nor is knowledge something we are born with. The human being must construct knowledge and reality. He does that little by little over many years.

1.2 Points of criticism

It is necessary to highlight some of the objections that have been raised to Piaget's work.

The concept of stages in Piaget's theory has encountered many objections. Ausubel (1964) does not wholly agree [7] with the ideas which Piaget put forward. He asserts that, firstly, the idea of 'stage' gives a false impression that development proceeds by a series of abrupt jerks rather than smoothly. Secondly, intellectual functioning at any one stage exhibits more variation than the concept of a stage would suggest. Thirdly, cross-cultural variability limits the usefulness of such a concept. Finally, the environment is more influential than Piaget admits.

Another objection is that [4] Piaget's work has not always satisfied the requirements of scientific research. For example, Piaget's samples are small, therefore, statistical analysis is meagre if not completely absent from the experimental reports which causes insufficient information to follow from other investigators. In other words, Piaget conducts his experiment to illustrate his point of view rather than to gain new knowledge.

1.3 Ausubel's assimilation theory of learning

Ausubel arrived on the scene in about 1963 with his book 'The Psychology of Meaningful Verbal Learning'. His work has captured much attention among educators in science education.

In Ausubel's theory of learning he states that the most essential single factor that influences learning is what the learner already knows (prior knowledge).

Gagné, another science educator, is concerned with prior knowledge also. The basis of his theory is that any section of knowledge can only be acquired by people who already possess certain prerequisite pieces of knowledge, which have their own prerequisites in turn. The theories of both Ausubel and Gagné are considered to be complementary theories of prior knowledge.

Ausubel's theory comprises seven major component concepts which account for his meaning of 'what the learner already knows': [8]

1.3.1 Meaningful learning versus Rote learning

Ausubel indicates that [9] meaningful learning occurs if the learning task can be related in a nonarbitrary, substantive (nonverbatim) fashion to relevant existing concepts or propositions in the learner's cognitive structure. Whereas rote learning takes place if the learning task comprises purely arbitrary associations and verbatim incorporation (or in a verbatim fashion) of new knowledge into the learner's cognitive structure.

Thus Ausubel postulates, that meaningful learning materializes when the learner's appropriate existing knowledge [10] interacts with the new learning. But rote learning may take place when no such interaction has occurred.

The distinction between rote and meaningful learning [8] is not a simple dichotomy since concepts are acquired idiosyncratically and vary from learner to learner according to their degree of linkage to, and differentiation from, other concepts. The rote-meaningful learning characterization is a continuum, with the relative degree of meaningfulness of a learning task effected both by the relevant cognitive differentiation and the learning set of the learner.

In general, meaningful learning [11] requires three conditions to be upheld:

(a) The material itself must be relatable to some hypothetical cognitive structure in a nonarbitrary and substantive fashion.

(b) The learner must have relevant ideas which relate to the material.

(c) The learner must also intend to relate these ideas to a cognitive structure in a nonarbitrary and substantive fashion.

Rote learning, on the other hand, requires three conditions:

(a) The material to be used must lack logical meaningfulness.

(b) The learner must lack the relevant ideas in his own cognitive structure.

(c) The learner must lack a meaningful learning set.

1.3.2 Subsumption

Ausubel uses this concept to represent the idiosyncratic nature of meaningful learning and to represent the fact that new knowledge is usually incorporated (subsumed) into more general concepts.

According to that, Ausubel notes that each learner's cognitive structure is unique therefore the learner's incorporation of new knowledge yields a cognitive interaction harvest which depends on which concepts or misconceptions the learner already has and the material that is presented. [12]

He asserts that new knowledge interacts with existing relevant concepts and is assimilated into these concepts, thus altering the form of both the anchoring concept and the new knowledge assimilated.

Ausubel has classified the anchoring concept as a subsumer and the process of meaningful learning results in the subsumption of new knowledge. His process of subsumption differs from Piaget's concept of assimilation in that new knowledge is linked to specifically relevant concepts and this process is continuous and superior changes in meaningful learning (or use of knowledge in problem solving) take place as a result of a growing differentiation and integration of relevant concepts in cognitive structure rather than as a result of Piaget's general stages of cognitive development.

Ausubel indicates that [8] the capability of older children to solve more complex problems is much greater than younger children since the overall level of differentiation and integration of older children's concepts is much more elaborate rather than because they have some unique cognitive capability (as Piaget stated).

1.3.3 Obliterative subsumption

Ausubel has introduced this concept to distinguish between 'meaningful forgetting' from normal forgetting as is usually observed in classrooms or in the psychology laboratory where rote learning predominates.

It is true that the knowledge which is acquired by meaningful learning may be recalled much longer than knowledge which acquired in rote learning. For instance, though a student may forget the formula for Boyle's law, he will still recall that there is an obvious relationship between pressure and the volume of gases. Specific details about Boyle's law may have been obliteratively subsumed, but the student has retained the concept's usefulness for learning new things about gases which remains as a positively functional element in cognitive structure. [8]

1.3.4 Progressive differentiation

What Ausubel means by progressive is that, from childhood onwards, the concepts one holds are being constantly modified, elaborated, made more precise, more exclusive and more inclusive.

It is important to realise that [12] the progressive differentiation of concepts is never complete for scientists as they are still differentiating their concepts.

As far as this process continues throughout adult life, Ausubel confirms [8] that any given concept is never acquired but is in the process of being differentiated.

In comparison with most children, most adults' acquisition and differentiation of concepts materializes with a radically more complex cognitive structure. The qualitative differences are due to the enormous variations that accrue for subsumption into a simple cognitive framework in contrast to the process when a much more elaborate, relevant cognitive framework is available. Therefore the qualitative differences are not due to different stages of cognitive functioning.

The variation among learners in the degree of differentiation explains why some adults eagerly approach new learning or problem solving with the naivety of children and, in contrast, why children, in some instances, think like adults.

1.3.5 Superordinate learning

While most new meaningful learning implies new instances or modifications of previously learned concepts or propositions, occasionally new concepts may be introduced that bear a superordinate relationship to prior concepts. For example, if the learner acquires the concept of the mole, he will relate atomic-molecular properties of matter to concepts of mass, weight, volume, and density of substances and to Avogadro's number : successful acquisition of concepts (superordinate learning) which leads him to employ concepts with new meaning and with new relationships to one another. [12]

1.3.6 Integrative reconciliation

Ausubel has suggested that [8] whenever superordinate learning happens integrative reconciliation happens, that is, when two or more concepts are found to relate to each other in a new way the integrative reconciliation of concepts may be materialized. For example, concepts like mass, weight, density, and gravity have unrelated or contradictory meanings for learners at the beginning, but later on they become integratively reconciled into a more powerful cognitive framework.

Additionally, it happens that integrative reconciliation may come into existence when learners recognise that different terms (concept labels) label the same concept, or that two distinct concepts are represented by the same label. Integrative reconciliation is important as soon as children start to recognise that language codes the meaning of concepts, and continues to be throughout life.

1.3.7 Advance organiser

This is a verbal statement presented to the learner [10] before the introduction of new knowledge. It is a pedagogical strategy that provides the learner with an alternative set of anchors or links if he does not possess appropriate subsumers, or if the subsumers are inadequately altered or developed to play their part in the new learning.

Ausubel considers an advance organiser as a cognitive bridge [12] between what the learner already knows and what is to be learned. This cognitive bridge is a small learning episode which is more general and more inclusive than the learning material.

The advance organiser has a role [8] in the facilitation of meaningful learning. Advance organisers probably facilitate the longevity and incorporability of meaningful learned material in three [11] different ways:

(a) They mobilize whatever relevant anchoring concepts are already established in the learner's cognitive structure and make them part of the subsuming unity.

(b) They make the subsumption of specifically relevant propositions possible.

(c) They invalidate much of the rote memorization to which learners often resort because, in general, learners need to learn every detail of an unfamiliar discipline before having obtained a sufficient number of key subsuming concepts.

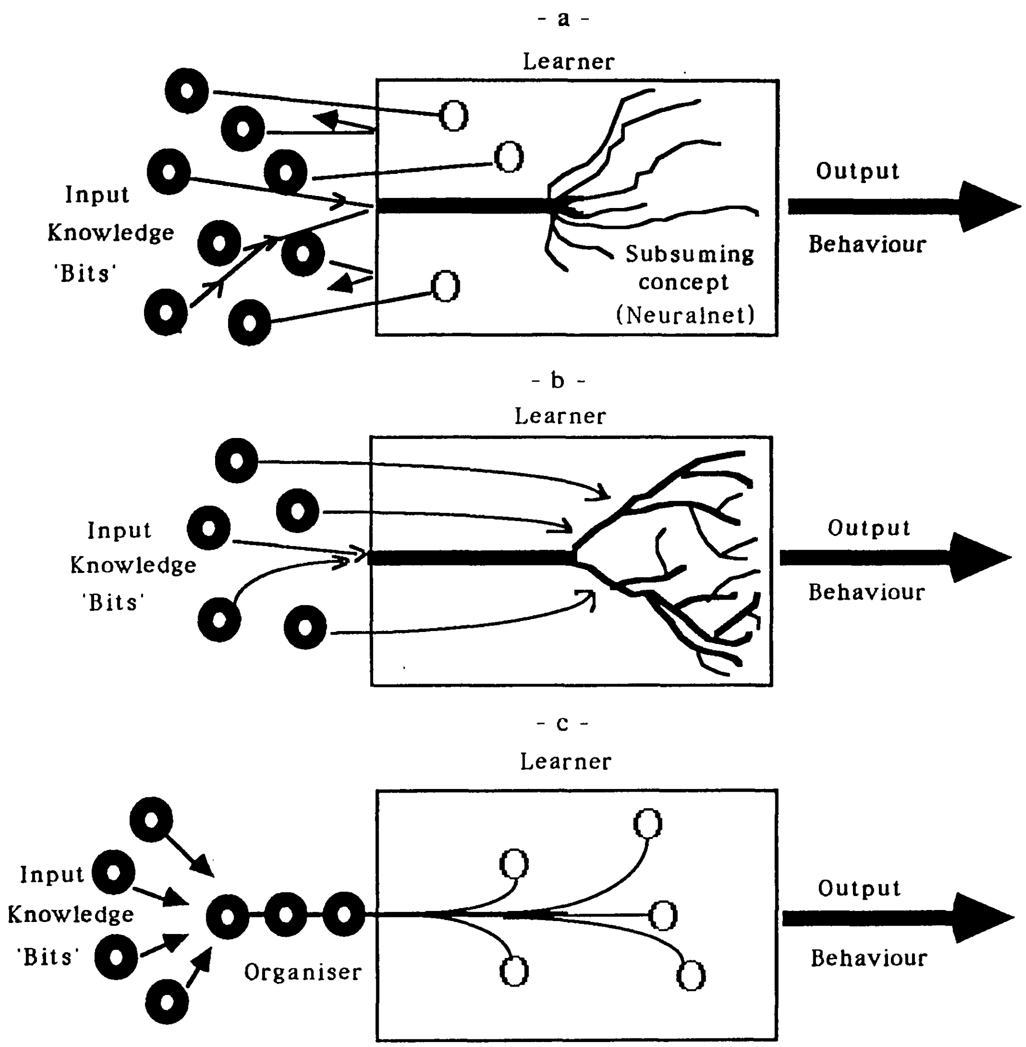


Figure 1.1(a) Schema showing that knowledge bits which can be associated with an existing concepts are accepted and 'subsumed' to enlarge and strengthen this concept (meaningful learning). Non-subsumable knowledge bits are not accepted by the learner, or are learned independently (rote learning).

Figure 1.1(b) Schema showing that additional meaningful learning can result in subsumption of prior concepts into larger, more inclusive concepts.

Figure 1.1(c) Schema showing that appropriate knowledge sequence can serve as 'organisers' to facilitate subsequent meaningful learning. (Extracted from Novak [13]).

Novak (1971) has suggested [13] pictorial representations of the roles of 'subsumers' and 'advance organisers' to support Ausubel's theory of learning and its basic propositions. The pictorial representations are shown in figure 1.1(a), 1.1(b), and 1.1(c).

Novak affirms that [10] subsumers and advance organisers suggest two types of learners;

(i) the learner who possess all relevant ideas or concepts in his prior knowledge and then uses than to subsume the new learning.

(ii) the learner who possesses no related ideas or concepts in his prior knowledge but obtains a subsuming base by rote learning a broad, general framework of ideas (advance organiser).

From the extreme types of learners, Ausubel's theory propounds that meaningful learning can occur by two processes. Firstly, the use of relevant and irrelevant subsumers in the prior knowledge and secondly in the use of advance organiser subsumers.

1.4 Reception learning versus Discovery learning

Reception learning is defined [14] as that type of learning where the regularities to be learned and their concept labels are shown manifestly to the learner.

Discovery learning, on the other hand, is defined as that form of learning which requires regularities in objects and/or events to be discovered firstly by the learner and abstracted from the general context in which they occur.

Ausubel asserts that [15] reception learning refers to the situation where the content of the learning task is presented to, rather than independently discovered by the learner. Whereas discovery learning refers to the principle content of what is to be learned; it is not given but must be independently discovered by the learner before he can internalize it.

The final form of what is to be learned in reception learning (rote or meaningful) is presented to the learner. He has not been involved in any independent discovery on his part. He needs to internalize or absorb the material that is presented to him so that it is accessible and renewable at some future date.

The task of discovery learning (for example, concept formation, rote or meaningful problem-solving) is to discover which of two maze routes leads to the goal, the definite nature of a relationship between two variables, and the common features of a number of diverse instances.

According to that, if the learner wants to attain discovery learning he must rearrange a given array of information and integrate it with his existing cognitive structure, and reorganise or transform the integrated combination in such away as to discover a missing means-end relationship. When this process is completed, the discovered content is internalized just as in reception learning.

We acquire large bodies of subject matter knowledge through reception learning. We may, sometimes, employ the knowledge which we acquired through reception in everyday problem-solving.

Ausubel compares reception and discovery learning. He indicates that discovery learning is a psychologically more involved process since it presupposes a problem-solving stage. Young children learn new concepts through autonomous discovery. However reception learning appears later developmentally and implies a greater degree of cognitive maturity. It is not really prominent until children become capable of internal mental operations and comprehend verbally presented topics in the absence of current concrete-empirical experience.

Novak (1979) has emphasized that [14] discovery learning occurs first of all with very young children in the process of concept formation, when new discoveries are made in a discipline.

It is reasonable to consider the cognitive functioning and psychological set of the learner as new knowledge is internalized so that it becomes essential to distinguish between acquiring knowledge arbitrarily (rote learning) and acquiring knowledge significantly (meaningful learning) since this varies substantially from learner to learner. Furthermore, meaningful learning varies along a continuum from almost pure rote to the highly meaningful.

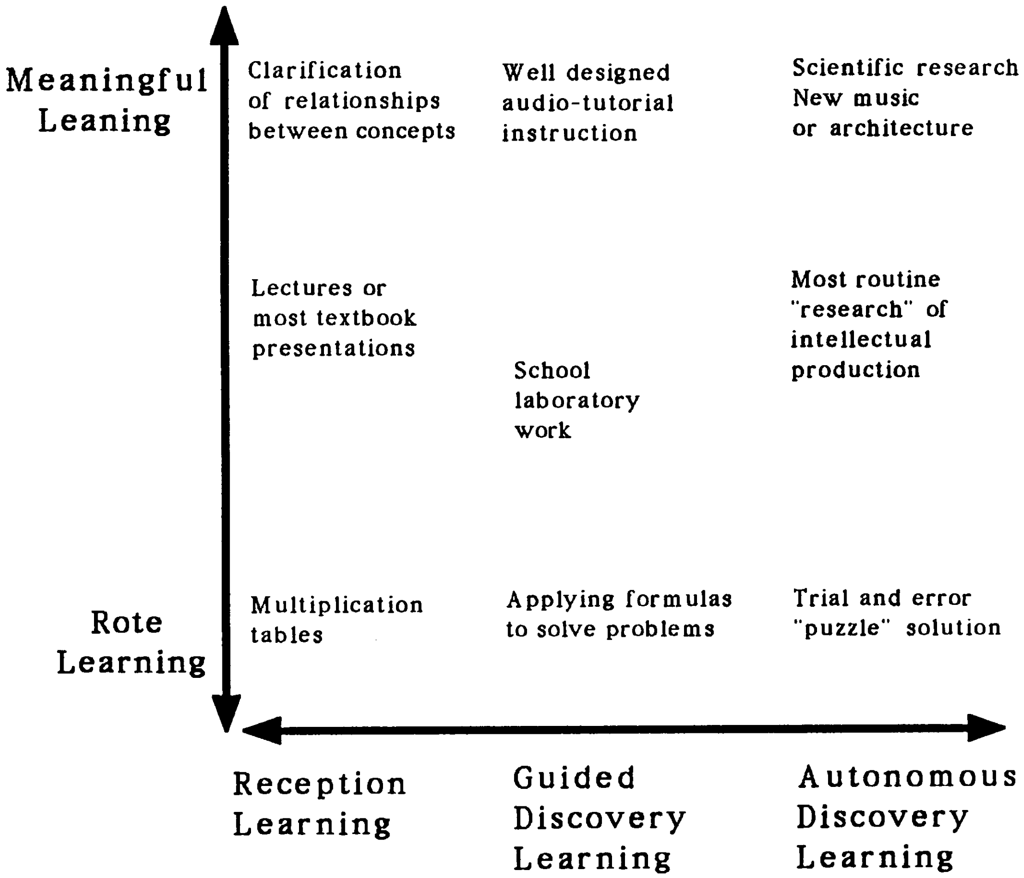


Figure 1.2 Reception and discovery learning are on a continuum distinct from rote learning and meaningful learning. Typical forms of learning are shown to illustrate representative different positions in the matrix.

Novak has presented a pattern showing the 'rote-meaningful' learning continuum as distinct from the 'reception-discovery' mode of information acquisition. The pattern is shown in figure 1.2.

1.5 Stages of intellectual development in Ausubel's theory

First of all, Ausubel (1969) considers [16] the gradual shift from concrete to abstract cognitive functioning as the most important change in intellectual development. It is profitable to start with understanding what Ausubel means by stages.

1.5.1 The meaning of stages

The term 'developmental stages' indicates a sequence of identifiable phases in an orderly progression of development which are qualitatively discriminable from adjacent phases and generally characteristic of most members of a broadly defined age group.

A given stage reflects the influence of both genic and environmental determinants, and can happen gradually or abruptly. Hence, Ausubel criticises Piaget's stages of development and he asserts that such stages seem to be quite irrelevant.

In contrast to Piaget, Ausubel emphasizes that a given stage cannot be expected to take place at the same age for all individuals, and there is no reason why its manner of achievement must necessarily be abrupt as long as each stage is qualitatively discontinuous in process from both the succeeding and preceding stage. Thus a certain amount of overlapping among age groups is inevitable.

Moreover, some overlapping and specificity are inevitable whenever development is determined by multiple, variable factors so that we can foresee complete consistency and generality of stage behaviour within an individual from one subject-matter area or level of difficulty to another.

Transitions from one stage to another do not occur simultaneously in all subject-matter areas and sub-areas because of firstly intrinsic differences in levels of subject-matter difficulty and secondly due to differences in ability and experimental background over different subject areas. [9,16]

1.5.2 The concrete/abstract dimension of intellectual development

This is divided [11] into three qualitatively distinct development stages, the pre-operational stage(which is not relevant to our study), the stage of concrete logical operations, and the stage of abstract logical operations.

Ausubel's view about *the concrete operational stage* confirms that the child is capable of comprehending concepts without proceeding through the abstracting phase characteristic of the learning of primary concepts. Without this abstracting phase concepts acquired are referred to as secondary abstractions (concepts). The child would be able mentally to construct a representative image embodying the meaning of a concept, if he is given only the stimulus support provided by concrete images of exemplars of criterial attributes.

Ausubel describes exemplars of the attributes, at the concrete operational stage, as 'props' to facilitate the learning of concepts. Therefore, the learner will depend on props in understanding or using their meanings, as soon as secondary concepts are acquired. Nevertheless, the learner's problems in understanding propositions involving secondary concepts, or manipulating propositions in problem solving remain unsolved, unless he is supplied with a particular exemplar for each of the abstractions involved.

It is reasonable to say that definite limitations can be seen, during this stage, on the child's ability to understand and manipulate abstract verbal propositions. These limitations tend to be too remotely removed from concrete empirical experience to be relatable to his cognitive structure. However, interpretation does not mean that autonomous discovery is needed before these propositions can be meaningfully learned; as long as concrete empirical experiences are made an integral part of the learning situation, the propositions are outstandingly learnable. These props also need not necessarily be nonverbal or tangible.

In *the abstract logical stage*, Ausubel points out that the third stage is somewhere near the beginning of the junior high-school period when the student decreases his dependence upon concrete empirical props in meaningfully relating abstracts relationships to cognitive structure. He improves at the first step of this stage when he begins to understand the meaning of secondary abstractions presented verbally to him without having to make even the limited use upon of props characteristic of concept learning in the second stage. Sometimes, he may need no more than a definition of a given attribute (without props) to relate it directly to his cognitive structure.

In adolescence, the freedom from reliance on props is reflected. The adolescent is capable of understanding and manipulating the meanings of propositions involving secondary abstractions with no need to refer to specific exemplars of the secondary abstractions involved. Moreover, he becomes capable of theorising and dealing with hypothetical relationships between ideas.

It is possible to distinguish, on a general basis, between the notion of Ausubel's abstract logical stage and the notion of Piaget's formal thinking stage.

Ausubel's notion is derived from acquiring the meaning of concepts or propositions whereas Piaget's notion is derived from a problem-solving task. So it is that Piaget ignores the gap between the ability to understand abstract concepts and the ability to solve problems.

1.6 A new-Piagetian theory of development

The theory was first proposed [17] by Pascual-Leone in 1969. It has been modified and elaborated since that time.

Pascual-Leone's theory of development is not intended to replace Piaget's, but merely to make it functional.

The Piaget's notion of schema [17,18] is employed, fundamentally, in this theory. Schemata are the subjective units of thought, that is, the mental blueprints which represent experience and are responsible for producing behaviour.

Pascual-Leone has classified schemata into three categories:

(a) *Figurative schemata* which are broad ideas within which a person can group and handle sub-ideas. It is possible to describe this category as the internal representations of items of information with which a subject is familiar, or of perceptual configurations which he can conceive.

(b) *Operative schemata* the schemata to illustrate the broad ideas that have been adapted and to extend the pattern which comes into existence from these ideas. This category can be described as the internal representations of functions (rules).

(c) *Executive schemata* which are techniques and ways of doing things with ideas and concepts.

The last category can be explained as the internal representations of procedures which are applied to particular problem situations in an attempt to reach particular objectives. The executive schemata, according to that, are responsible for determining what figurative and operative schema a subject activates in any particular situation.

However, schemata could be seen as similar in that they are all highly active, functional units, and consist of two components;

(i) an initial set of conditions to which they apply.

(ii) a subsequent set of conditions which they can generate.

The child is born with an innate repertoire of sensory motor schemata. Other schemata may be acquired in two ways: the first way is by the modification of an old schema and the second is by the combination and consolidation of several old schema.

Pascual-Leone's theory has assumed [17] that subjects use several schemata in their everyday interaction with the world. This operation depends upon their mode of thought. The following statements are presumed to characterize the processes of thought:

(a) Subjects will try initially to activate some general executive schema when they attempt to solve any problem. The schemata which the subjects employ depend upon the nature of the problem-constraints, the nature of the perceptual field, of their past experience in problem solving, and of their emotional reaction to the situation.

(b) The schema directs the activation of a sequence of figurative and operative schema soon after it is activated.

(c) The sequence of figurative and operative schemata consists of separate 'mental steps'. Each of these comprises of an obvious operation, in which an operative schema acts upon one or more figurative schemata, and produces a new figurative schema.

(d) It is possible to utilise the figurative schemata, which are obtained, in future operations since they may be carried forward or 'rehearsed'.

(e) The activation or rehearsal of any schema requires the application of 'mental effort'. It will be operated on an individual basis because the amount of mental effort, applied at any one moment, is limited therefore the number of schemata used in any one mental step, is limited also.

(f) If the generation of schemata (or a schema) has reached its peak, the executive schema directs an appropriate terminal response and ceases to be active.

(g) The last point deals with what Piaget has labelled 'equilibration'. It is a way in which schemata are being modified and changed qualitatively through assimilation and accommodation to able the individual to interpret events in the outside world.

Nevertheless, for any particular subject to solve any particular problem [17] four additional factors apply:

(a) The repertoire of schemata which subjects bring to the problem. The subject's repertoire will be increased in complexity and accuracy with experience in life.

(b) The maximum number of schemata which are attainable by the subject's psychological system at any one time. Moreover, the M-power or the maximum mental effort is presumed to vary both within and across age groups.

Case emphasises [17] that M-power represents the maximum number of schemata which can be coordinated at the same time in the way of executing a series of mental transformations. Pascual-Leone assumes that [18] a distinction can be made between the subject's maximum capacity 'structural M' and his 'functional M' which is the amount of M that he used in any particular moment. The 'functional M' oscillates between zero to 'structural M'. In another study, Pascual-Leone [19] explains the M-power as a finite 'central computing space'. The size of the M-power is assumed [17] to increase linearly with age, according to the following scale:

Age	Development substage	M power
3-4	Early preoperations	e+1
5-6	Late preoperations	e+2
7-8	Early concrete operations	e+3
9-10	Middle concrete operations	e+4
11-12	Late concrete-early formal operations	e+5
13-14	Middle formal operations	e+6
15-16	Late formal operations	e+7

In the above notation, the e is used to denote the space required for the executive schemata.

The M power increases with age at the rate of one schema or unit every two years, from childhood up to maturity. That means age-related predictions can control the influence of manipulating the information load characteristics of tasks.

(c) Another factor related to problem success is the tendency to utilise the full M-power that is available for the subject. However, certain subjects are habitually low M-processors. They look at the problem in the simplest manner possible, in other words, certain subjects involve the least possible mental efforts.

(d) The last factor is the relative weight which a subject gives to cues from the perceptual field, as opposed to cues from other sources like task instructions, in selecting an executive schema. Subjects are presumed to vary in a given trend to give weight to such salient but misleading cues, and individual variances in a trend are stable across tasks and across time.

The individual variances which are described in (c) and (d) are assumed to be highly correlated, in addition to being believed to illustrate the cognitive style dimension 'field dependence-field independence'.

Pascual-Leone's interpretation [17] for field dependent subjects is that they are habitually low M-processors, and tend to assign higher weight to perceptual cues than to cues provided by the task instructions in situations where these two sets of cues propound conflicting executive schemata. Field-independent subjects, however, tend to be high M-processors, and assign a higher weight to the task instructions than to perceptual cues in such conflicting situations.

The maximum mental effort M (the computing space or the central processor) with the operative superschemata [18] are responsible for the transformation and coordination of the information initially existent in the psychological system at any time.

The hypothesis [20] suggests, that the M-space increases with age and that the power value of the central computing space M defines the different development stages of Piaget.

Furthermore, Pascual-Leone experiments with subjects in the encoding and decoding of symbols, and he affirms that, even if M belongs to a higher logical type than its linguistic product, it operates equally well in a nonlinguistic context.

Case (1974) concludes [21] that the new-Piagetian theory make reasonably accurate performance predictions in relatively unconstrained problem situations, provided that some supplementary evidence is available as to what range of strategies are possible, and which of these strategies were actually employed.

He adds that the theory has the power to predict the interaction between instruction and development, provided it is realised that the M-space required to acquire a strategy is not necessarily identical to that required to employ it.

In brief the conclusion which Case arrived at concerning the new-Piagetian theory is that:

"The theory has the potential to make detailed performance predictions in relatively, unconstrained developmental problems, provided the possible mental strategies which a subject might use can be clearly specified, and provided they can be conveniently assessed".

Niaz indicates [22] that the new-Piagetian theory confirms that the activity of schemata could be increased by cognitive 'operators', known as 'scheme boosters'.

The new-Piagetian model [22] displays that the subject's performance would depend on;

(i) the development of formal operational thinking.

(ii) M-space (mental capacity) for information processing.

(iii) the ability to disembed relevant information.

(iv) previous experience.

Niaz, in another study [23], concludes that the horizontal decalages in the Piagetian literature could be accounted for by increasing demands of information processing.

CHAPTER TWO

Information processing models for learning

2.1 The human memory

Commonly, psychologists have used the word 'memory' [24] to denote the capacity to remember. Processing is the means by which the retention and retrieval of information is operated.

The data are assumed [25] to be stored in our memory in a very accurate manner. The information processing approach of mental activity involves these data, when the implementation is required by some control mechanism in the brain.

Differences between psychologists concerning the human memory are in terms of: which factors dominate our memory; how particular information is stored; what is used when processing this sort of information; and at which stage the information is retrieved.

2.2 Components of memory

Evidence in the field of memory clearly indicates that the human memory has more than one store and more than one retention system; the sensory memory, the short-term memory, and the long term-memory.

2.2.1 Sensory memory

This form of memory exists for a very short period of time. The image of stimuli is registered for a few hundred milliseconds and will then be completely forgotten. The sensory memory is defined [26] as a continuation or persistence of the process involved in perceiving a stimulus when that stimulus is no longer physically present.

The sensory memory is associated with each of our senses, especially with the auditory stimulus called 'echoic' memory and the visual stimulus called 'iconic' memory.

This type of memory [27] has several features which are primary features of a sensory information store:

a. It retains information for a short time: 0.1 - 0.5 second.

b. It contains much more detailed information than the information which is stored in short-term memory.

c. It is impossible to get an 'instant reply' feature from the sensory memory store.

d. It is considered a transient information store as it operates for a very limited time.

e. It operates in perceptual processing.

2.2.2 Short-term memory

This type of memory has small capacity but great speed. If new information enters [28] our memory, the short-term memory will hold a section of it for a while since it has a limited capacity. The information which is held in the short-term memory is usually the information which we are paying attention to.

The short-term memory allows [29] an easy recall of small amounts of information (such as a new telephone number) over a short time. The capacity of this memory seems to be between five and nine chunks of information.

Miller (1956) suggests [30] that short-term capacity is about 7 ± 2 chunks. This proposal has gained wide acceptance. In chess, for example, many researchers argue that the chess memory data confirms the idea that the perceiver of the chess board stores about 7 familiar units or chunks.

The information which comes to the short-term memory decays rapidly since this type of memory operates so quickly and has a very limited capacity. However, no decay will occur if the information is constantly updated and therefore we can easily lose the thread of our thoughts when something distracts our memory; when our current thoughts are replaced by a piece of data which seems to be more fruitful or suitable. It is possible to summarise [27] the prevalent features of short-term memory:

a. It retains information for a few seconds to a few minutes.
b. It involves the immediate interpretation of events.
c. It constitutes a limited information store.
d. It is the site of information storage while one attempts to organise and store information in the long-term memory.
e. It allows the information to reach this level more or less automatically.

2.2.3 Long-term memory

This type of memory requires [29] a more conscious effort of memorization. Long-term memory has an unlimited capacity for practical purposes and it always encodes the information which is in its most lasting form.

Most hypotheses suggest [5] that all the information which enters the long-term memory does not decay but tends to be kept permanently. However, it is essential to realise that the long-term memory has a greater capacity to store the information permanently than either of the two types of memory which have been mentioned in this chapter.

Moreover, it is assumed that [29] the storage of a chunk of information in the long-term memory takes between 2-10 seconds longer than the retrieval of it, which means that we may retrieve more quickly many chunks from long-term memory while our memory capacity to store chunks in it is much less.

Finally, we may summarise the projected primary features [27] of this type of memory:

a. This memory has a permanent unlimited capacity.

b. It has a retrieval capability for information(the information which is composed prior to storage in it).

c. Search procedures would be required to retrieve chunks of information from long-term memory.

d. A good deal of attention is required to transfer a piece of information from short-term to long-term memory.

What becomes apparent from the above information is that [24] what distinguishes the short-term memory from the long-term is that no complete loss of memory will occur among materials which have reached the long-term memory system, whereas some information may be lost and leave no permanent record in the short-term system.

Figure 2.1 [5] shows how the three types of memory operate and interact and how information is transferred from one store to another.

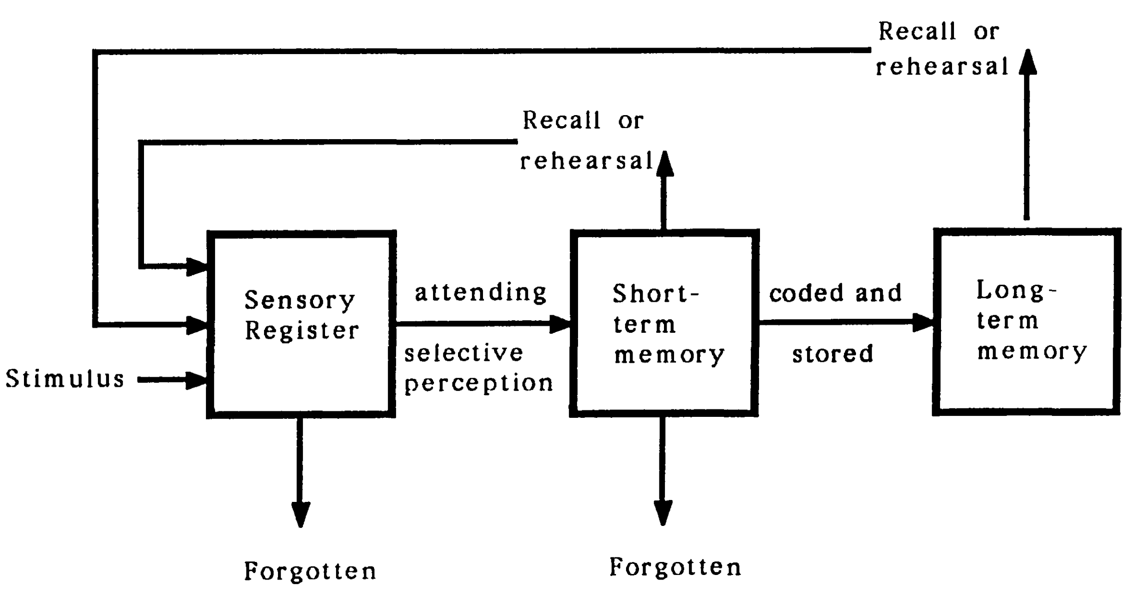


Figure 2. 1 **Hypothetical structures of the information processing model of memory as it has shown by Child (1973).**

2.3 Working memory

Working memory [31] is a small space or a small capacity in our brain (specifically in short-term memory) in which memory is operated and symbols may be temporarily held. The important aspect of this capacity is that it enables us to retrieve the information from its space after it has been held.

Johnstone emphasises [32] that working memory is limited in its size and defines working memory as "that part of the brain where we hold information, work upon it, organise it, and shape it, before storing it in long-term memory for further use".

People require the working memory to execute most tasks. It is the place in which all operations on data are carried out. The properties of working memory depend upon the sort of task being carried out.

Nevertheless, working memory is limited in capacity so that all operations may not occur simultaneously without impairing its performance.

Furthermore, studies in working memory suggest [33] that learners are incapable of emitting two unrelated responses at the same time and that one response will occur before the second one which is almost invariably delayed.

The human memory observes [34] the events around it, and may process such observations within a very limited space in the short-term memory (working memory) and this part allows the observation to pass into long-term memory for permanent storage or retrieval, depending upon demand.

2.4 Memory process

Stewart and Atkin give [27] a useful description of our memory system when they consider it as analogous to a library system. The book can be easily found if put on its shelf according to the library system and we may retrieve any particular book by using a suitable search procedure. The human memory has a similar card-cataloging system and it can easily recognise the information which has been retained.

The coding of stored information in the human memory requires [24] an appreciable amount of processing to ensure that the memory can retrieve it at a later date.

The ability of the human being to retrieve any sort of information may be affected by the following factors:

a. The attention functions.

b. The organisational factors which allow familiar items to be recalled more correctly than unfamiliar items.

c. The way of encoding and storing items (it needs to be at the core of the mechanisms of memory).

d. Producing a sort of chunking. (see 2.5 below)

e. The rehearsal to ensure a successful retrieval.

Additionally, the human memory has a set of manipulative rules [27] which are the rules of logic such as induction and deduction. These rules seem to be important since a knowledge of them influences the process of the storage of information.

Anderson uses a useful picture has shown in figure 2.2 [35] for mental information processing. He calls his theory ACT (Adaption Control Theory).

Anderson divided the long-term memory of the human being into two parts;

(i) the *DECLARATIVE* memory which contains all the facts that we already know.

(ii) the *PROCEDURAL* memory which contains procedures for the actions which we know how to perform.

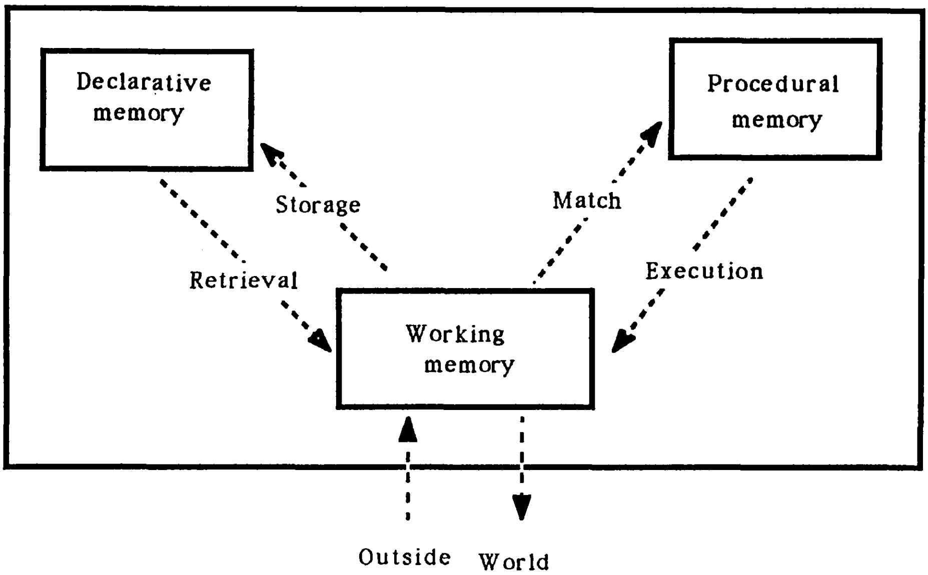


Figure 2.2 The Adaptive Control Theory ACT adaptation from Anderson(1983).

In brief, the declarative memory [36] is responsible for recognising all facts which the human being has learnt and makes them knowable to himself. The declarative memory stores all schemata about facts therefore it is possible to retrieve any piece of information from it by the process of reminiscence.

The procedural memory is the second part of long-term memory. It is full of productions representing conditions for actions. The process taking place in this part of the memory matches the production of any action with what is stored and detects an appropriate action automatically, thus the procedural memory should be responsible for all actions.

The working memory capacity, according to this theory, would seem to be very important in transferring stimulus from outside the subject into the long-term memory and receiving the responses to transfer them again to the world.

2.5 Chunking and memory

As we mentioned in Chapter 1 (Pascual-Leone hypothesis), the word 'chunk' was employed firstly by Miller (1956) in his magical number seven artical. He emphasises [30] that a chunk means a word, letter or digit which describes a familiar item or unit.

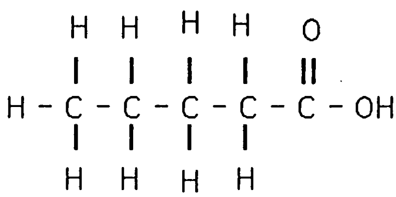
Miller confirms that the human's ability to process information depends upon the span of absolute judgment which seems to be limited by the amount of information, and the span of immediate memory which seems to be limited by the number of items. Moreover, Miller discriminates between bits and chunks of information and he states: "I have fallen into the custom of distinction between *bits* of information and *chunks* of information. Then I can say that the number of bits of information is constant for absolute judgment and the number of chunks of information is constant for immediate memory. The span of immediate memory seems to be almost independent of the number of bits per chunk, at least over the range that has been examined to date".

Information can build larger and larger chunks (or units) in our memory by adding more and more data to each one. In other words, it has the potential to increase the *capacity* of chunks rather than the *number* of them.

An example of chunks can be found when we learn [29] to read. At first we must recognise letters, so we see the components of the letters as chunks by using a recognition procedure to recognise each letter. If we practice this, we may begin to see each letter as a chunk because we are no longer aware of performing it consciously. If we do more practice later, we may see short words as chunks, until we eventually begin to see long words or even short phrases as chunks. We automatically and unconsciously would become able to read fluently by absorbing meaning from a string of printed symbols.

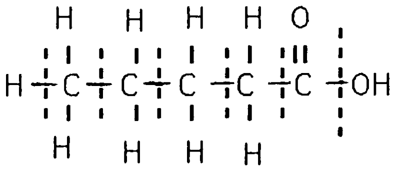
In chess, according to Miller's suggestion (short-term memory capacity was about 7 ± 2 chunks), the perceivers of the chess board store about 7 familiar units or chunks, but the chess master's 7 chunks of information are much richer than those of the novices. This means that the chess master has larger units than the others but manipulates the same number of units.

In chemistry, this theory applies with 'chemistry masters' and 'chemistry novices'. Generally, their ability to chunk [37] the information presented in a chemical situation could be distinguished. For instance, we can see a 'master' presented with a formula such as:



N- Pentanoic acid

A master is able to memorize and reproduce it easily, he would see it as two chunks: a butyl group, and a carboxyl group, but a 'novice' would see the configuration as 17 letters joined by single or double lines.



Finally, Simon (1974) assumes [38] that the change with age in the digit span of the human memory is due to the growth of encoded strings in the human's chunks.

2.6 Mental overload

As we stated before, the working memory is a limited space in which we hold information for a while and work upon it therefore it is a shared holding/thinking space If the information we are concerned with reaches [39] the upper limits of our working memory space, an overloading in the capacity of working memory could occur and a loss in productivity may arise.

'Overloading' means that the working memory of limited capacity is overloaded with too many pieces of incoming data, so that no processing of the data can take place in our shared memory space. Moreover, we may lose our ability to chunk and sequence any set of information.

According to Miller's suggestion and with a series of information tasks of increasing complexity, we would expect a sudden drop in performance beyond the point where the working memory load exceeds 7 ± 2 pieces.

Johnstone and Kellet [37] have emphasised that if a task exceeds the human's working memory capacity or space, it requires a good degree of understanding to chunk the many pieces into a workable load, or the subject must have a 'trick' which enables him to lighten the load.

In practical work, the overloading of working memory also appears when the learner is incapable of discriminating between the 'noise' (which the teacher considers unimportant information) and the 'signal' (which the teacher considers important information) in the laboratory.

Also involved is the use of language. Whereas familiar vocabulary tells the learner what we want to say and allows him to solve his problem with ease, unfamiliar vocabulary occupies valuable working space and causes a loss in performance.

2.7 A hypothesis involving the overloading of working memory capacity

In his work, Johnstone determined [40] that a sudden drop in the learner's performance was apparent when any task load exceeded the upper limit of the learner's working memory capacity. Johnstone states: "we began to go back over the areas of reported difficulty to look for what amounted to an overload of the working memory - the part of the mind in which recalled and new material interact in the process of thinking, reasoning, and learning. If this working area is of finite size, what phenomena would we expect to find if we presented students with problems or learning situations of increasing load? Where the size of the load was small we could expect a good response to problems. As this load increased we might still expect good performance provided the load was within the capacity of the working memory. However, as soon as the load exceeded this upper limit, performance would drop suddenly".

In the field of science Johnstone indicates [32] that three aspects can prove to be detrimental to students: the nature of the science; the methods of teaching a science; and the ways in which students learn. A combination of these difficulties could easily overload a student's working memory capacity.

Teachers, on the other hand, must be aware of how to cooperate with the students' working memory capacity since it has a limited size. For example, if a teacher, in teaching the concept of mole in a thoughtless way, may leave no space for thought and organisation in the students' working memory so that faulty or even no learning may result.

Teachers will be at fault if they believe that education involves the simple transmission of a complete set of ideas from their minds into the minds of students. Rote learning is easily utilised in this situation but does not guarantee that genuine understanding exists. This complies, to a great extent, with Ausubel's thesis as was discribed in the preceding chapter. The student's memory has the ability to analyse and organise received information and to absorb such information.

Our use of language constitutes another source to information overloading in teaching science. For instance, the use of ornate and convoluted language in teaching chemistry creates an overload in the working memory capacity of students. Therefore our hypothesis suggests that teachers should employ familiar vocabularies instead of unfamiliar vocabularies to facilitate chemistry learning.

2.8 The laboratory and our overloading hypothesis of working memory capacity

We stated previously in this chapter that the student in the laboratory may lose his concentration and his working memory capacity could be overloaded if he becomes unable to differentiate between the 'noise' (irrelevant information) and the 'signal' (relevant information).

Johnstone and Wham have suggested a useful picture that has exhibited in figure 2.3 [41] showing how the student's working memory capacity could be overloaded in practical work. According to this model, a student may reach a state of unstable overload in the laboratory and will feel that he cannot relate to the teacher, the working materials, and the text.

Johnstone and Wham emphasise that there are several means by which to reduce the 'noise' in the laboratory and enhance the 'signal':

a. Teachers should give a lucid and concise explanation of the purpose of the experiment, or perhaps even go so far as to incorporate such a statement in an instruction manual.
b. Enhance the 'signal' by clarifying what is preliminary, peripheral and preparatory. Again, an instruction manual may be used.
c. Books or instruction manuals could be reconstructed to ensure that students would understand each constituent of the experiment (it is possible to use visual means such as pictures and photographs and thus curtail over elaboration).
d. Teaching skills which are both pertinent and applicable to the students in advance would mean that they could employ these skills in some later investigation.

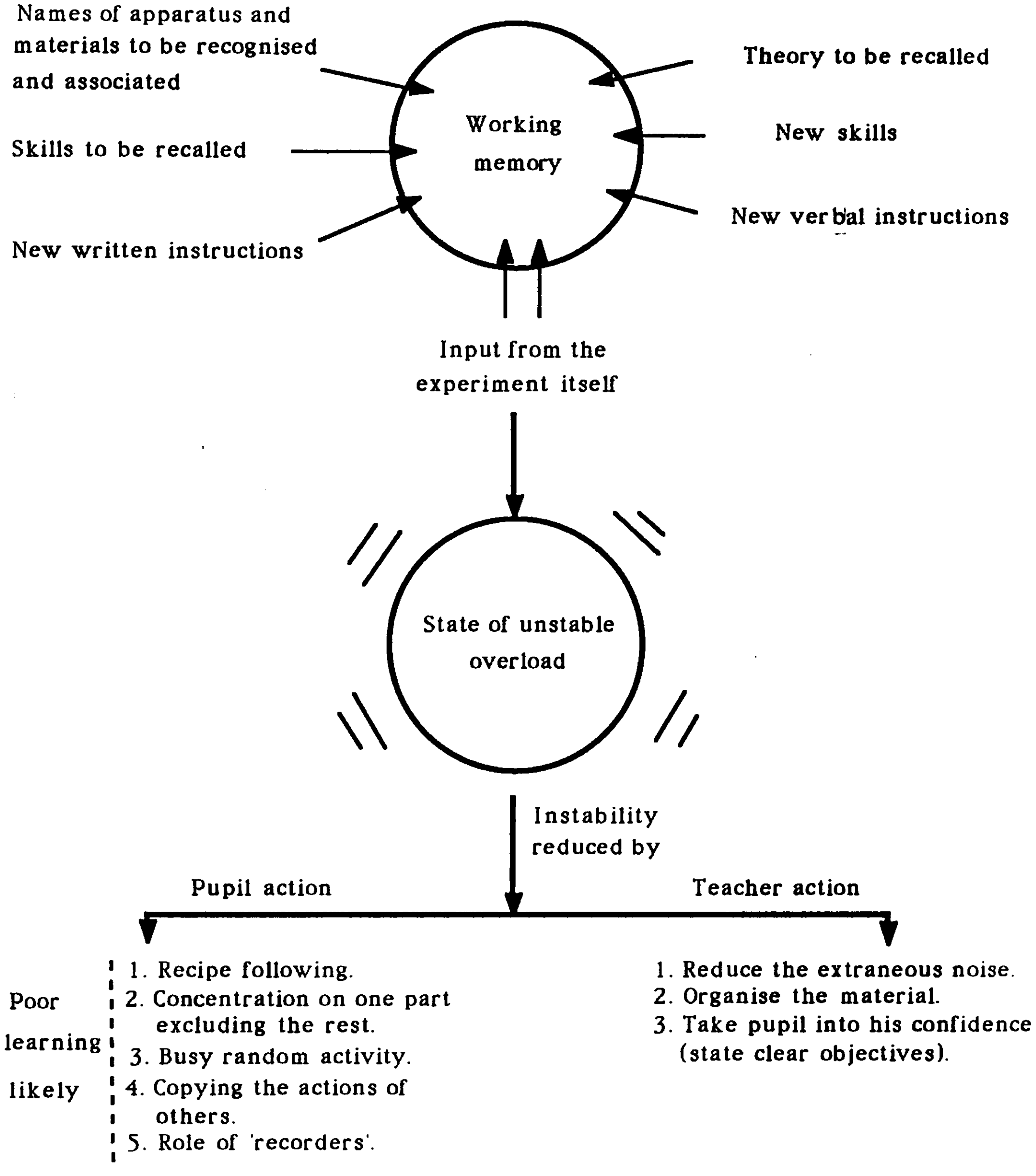


Figure 2.3 Unstable overload in practical work as it has shown by Johnstone & Wham (1982).

2.9 A predictive model based upon information processing capacity

It was stated earlier in this chapter that there is a limited area in our mind where we hold information and manipulate it. We called this area the working memory.

The information processing hypothesis, in general, reflects the way in which our memory encodes, stores, and retrieves information. We retrieve information by a process of the recovery of stored information from memory. The storage of information was discussed previously in terms of sensory, short and long term memories.

The ability of the human being to encode a set of information depends upon the given size of the working memory capacity. Within the human's working memory ideas are both held and thought about simultaneously. For example, when we try to solve any simple arithmetical problem or as we try to remember somebody's phone number, the function of the working memory capacity would begin to operate.

Moreover, the information which enters working memory space may be displaced unless an efficient system is instigated which would manipulate and organise such information in away which would incur no loss.

Miller (1956) indicates [30] that it is possible to encode information in a recognisable grouping by making chunks. Each chunk is controlled by previous knowledge and skills.

In chemistry, we could apply that by calculating the number of thought steps involved in any particular question for the least sophisticated learner.

Johnstone and El-Banna [42] have given the following example:

"What volume of 1.0M hydrochloric acid would react exactly with 10.0g of chalk?

1. Chalk is Calcium Carbonate (recall).
2. Calcium Carbonate is $CaCO_3$ (recall).
3. Formula mass = 100g mol^{-1} (calculate or recall).
4. Therefore 10g is 1/10 mole (deduce).
5. Write equation for reaction (recall product and formulae).
6. Balance (recall skill).
7. Deduce mole relationship.
8. Therefore 1/10 mole $CaCO_3$ = 1/5 mole HCl (deduce).

9. 1/5 mole HCl is 200 ml of 1.0M HCl (deduce).

This has also been logically sequenced.

A non novice (teacher) might treat the same problem as follows:

1. 10g chalk is 1/10 mole $CaCO_3$ (recall). {one complex chunk}

2. Mole ratio of HCl to $CaCO_3$ is 2:1 (experience chunk).

3. 1/5 mole of 1.0M HCl is 200 ml.

For a pupil, the problem might be beyond his capacity to hold, organise and sequence and solve. The teacher would see it as a trivial problem talking up only a small part of his thought/memory capacity".

In our information processing hypothesis we deal with three main parameters:

a. Y- means the *mental strategy* that the learner employs to solve a task (contains schema, tricks, techniques and previous knowledge).

b. Z- means the *demand* that the problem puts on the learner's mental capacity.

c. X- means the *working memory capacity* that the learner has.

Scardamalia, M (1977) defines [43] Z-demand as the maximum number of schemata that the learner must activate simultaneously in order to execute a task through an attentional process.

The X-space means the mental capacity or the working memory capacity introduced by Pascaul-Leone as M capacity. As we argued in Chapter 1, it has been found [17] that X-space increases with age at the rate of one unit every two years up to maturity.

Y-strategy represents an essential process in teaching and learning since we, as teachers, have the ability to develop and improve this process in the mind of the learner.

If we want the learner to be capable of improving his or her performance on the task we might:

a. Provide him or her with a more sophisticated mental strategy Y for executing the task.

b. Decrease the Z-demand of the task which the learner applies spontaneously by dealing with small parts of the problem one at a time and by associating incoming information with ideas and concepts which the learner has already acquired.

Johnstone and El-Banna advanced [42] a new simplified model for thinking/memory capacity in Figure 2.4 .

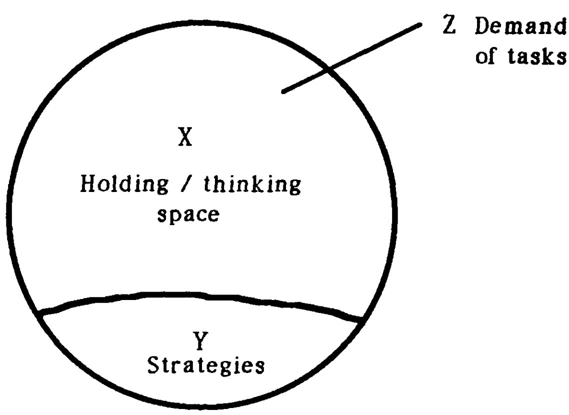


Figure 2.4 Johnstone & El-Banna model of thinking/memory capacity.

They suggested that our working memory space (named M-operator by Pascaul-Leone) holds ideas while we think about them. Y strategies (schemata, tricks, techniques and previous knowledge) are employed to solve our problems. Z-demand represents the load of any task which enters our mind.

A student with capacity X, given a learning or problem solving task of complexity Z, can succeed if $Z \leq X$, but he will fail if $Z > X$ unless he can operate on Z with all the techniques in Y to allow Z to be organised and become less than X.

The hypothesis suggests that a negative correlation will be found between the facility value F.V. (a percentage of the sample who solve problems correctly) versus Z-demand which represents the number of thought steps in each question (a question complexity) as shown in figure 2.4 .

The curve which comes out is S-shaped. The sample was made from students whose thinking/memory capacity ranged over the whole 7 ± 2 (working memory capacity was measured by types of tests which will be dealt with in the following chapters). There is a vertical section in this curve which emerges between five and six on the Z-demand axis (which is similar to 7 ± 2 in Miller's hypothesis).

An interpretation of the vertical section (a sudden drop) is that the Z-demand exceeds the capacity X of a learner but that it does not fall to zero. Johnstone and El-Banna remarked that: "the curve was also reminiscent of the shape one would expect to obtain for a phenomenon subject to catastrophe theory, that is 'holding up' to a point, followed by a sudden drop to a lower level beyond that point. However, the curve did

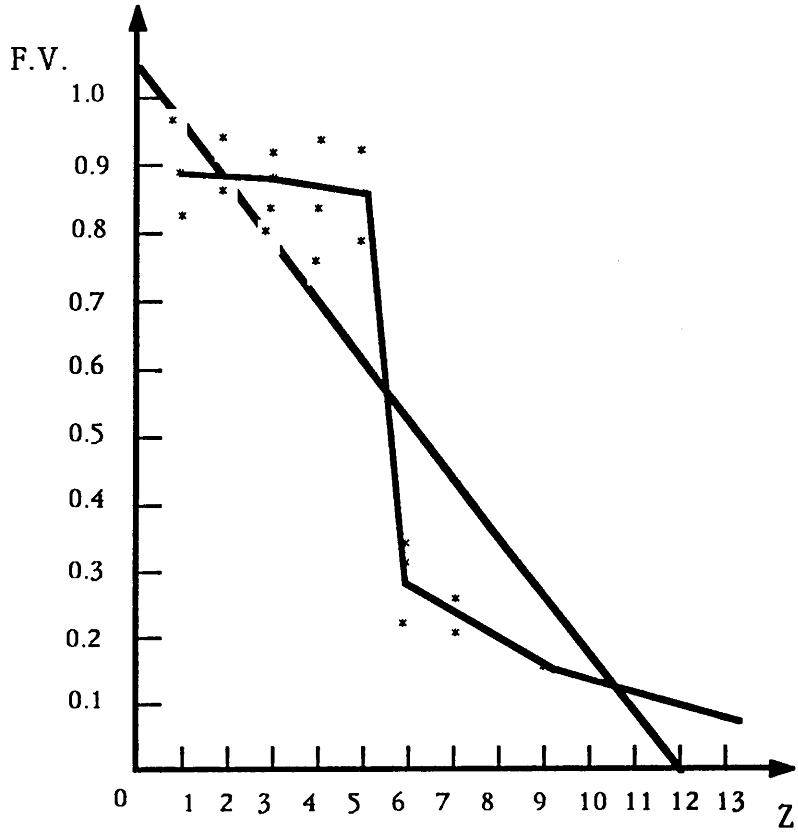


Figure 2.5 Correlation between facility value (FV) and questions complexity (Z) as shown by Johnstone & El-Banna (1986).

not quite fit, because it did not drop to zero, but slowly sank from facility value (F.V.) of about 0.35 to 0.10".

Finally, it is possible to distinguish between Miller's and Johnstone's work in short-term memory. Miller emphasises that the function of short-term memory is to *hold* the information (7 ± 2) *without manipulating it.* The amount of the information in short-term memory could be increased by increasing the amount of the information per chunk or unit.

Johnstone has paid attention to the function of working memory. He emphasises that working memory is responsible for *holding* the information and *thinking* about it (*manipulating*), and that means working memory capacity is smaller than short-term memory capacity in that some part of working memory is given over to operations, techniques, etc. Therefore, our working memory model is probably nearer to 6 ± 2, and that allows some space for operations.

CHAPTER THREE

The hypothesis applied to tertiary level chemistry 1986-1987

3.1 The application of holding/thinking space in chemistry

In Chapter 2 the hypothesis was discussed which considered a holding/ thinking space (working memory capacity) to be the maximum number of pieces of information or chunks which can be held in minds of the subjects at any one given time during the solving of their problems.

Previous research found out that this idea could be applied in chemistry. The subject fails to solve a problem if it exceeds his holding/thinking space (X), unless the subject employs a specific strategy which may help him to succeed.

In 1986, research was conducted upon first year science students who were studying chemistry as part of a biology degree at Glasgow university. The students' working memory capacity was measured and then their progress was traced from the beginning of the first term till the end of the last term in 1987, using all the data which was obtained from the students' performance in chemistry examinations and comparing that with their assessed working memory capacity.

It is possible to consider this research as a continuation of work which had been done in the information processing models.

3.2 The types of tests

The practical work of the research began by measuring the working memory capacity of subjects. Two types of tests were utilized for this purpose; 'a digit span backwards test', and 'a figure intersection test'.

3.2.1 Digit Span Test (DST)

The digit span test has been used since the nineteenth century: Claxton mentions that [44] Galton used the digit span test in 1883.

Worth and Schlosberg have stated in their book [45] that Jacobs (1887) used this test and that he handed out lists of 3-12 digits for subjects to work with. Jacobs's experiment measured the memory span of subjects. He recited numbers to the subjects and they then had to repeat these numbers in an identical order.

However, this present research applied the digit span test by two ways; the 'digit forward test' (DFT) which was used by reading a set of digits to the subjects and asking them to write the digits down in its order, this way used only to settle the subjects results otherwise it is to be ignored. The second way of the digit span test is called 'digit backward test' (DBT) which was applied by reading a set of digits to the subjects and asking them to write the digits down in reverse order, this way used to measure the size of holding/thinking space.

The design of the sheet for the digit backward test is to be found in appendix 1. A subject was given this sheet and was required to listen to the instructions and the digits from a tape recorder.

The instructions explain that the first part of this test is to write the digits down in the same order (under forward section) and then to listen carefully to the second part of the test and to write again the digits down but in reverse order (under backward section). The digit backward test needs two important conditions;

(i) the subject must not start writing until the reader has finished each particular set of digits.

(ii) the subject is not allowed to write down the set of digits from right to left.

The subject must listen very carefully to the digits and try to reverse each particular set of digits in his mind and then write them from left to right.

The experimenter gives the subject about one second per digit to allow him sufficient time to enter it onto his test sheet. Moreover, the design of the grid in the test sheet allows two lines for every digit from 2-8. The speaker of the test will start by giving the subject two digits and then he increases gradually the number of digits till eight.

The marker accepts one correct answer from the two rows and the reversed grid will be taken only since it reveals the ability of the subject for holding a set of digits for a few seconds and manipulating them (reversing every set of digits). The upper limit that the subject reached in reversing the number of digits is decided to be his capacity.

In brief, the score of the digit backward test reflects the size of holding/thinking space in the minds of the subject.

3.2.2 Figure Intersection Test (FIT)

This test was devised and used by Pascual-Leone and Smith in 1969 [43]. It is a test which asks subjects to find the intersecting area of a number of simple shapes which overlap to form a complex design.

The figure intersection test has many complex designs and each has from two to nine simple geometric shapes overlapping and the subjects must find the intersection area between these shapes.

A sample of this test is to be found in appendix 2(a). The test is exemplified on the first page of the test booklet and some examples have been provided to practice with. The subject is required to look at the shapes on the right hand side in which the separate figures are displayed; then he must shade in the common area on the left hand side where the same shapes have overlapped. Moreover, the designer of the test has incorporated one more geometric, and irrelevant, shape in some of the overlap figures in order to 'confuse' the subject.

The figure intersection test contains 31 figures distributed over six sets;

(i) each set contains five geometric figures except the second set which contains six geometric figures.

(ii) the number of figures for the first, second, third, fourth, fifth, and the sixth sets is 5, 6, 5, 5, 5, 5 successively.

(iii) the number of items (shapes) in each figure of the first, second, third, fourth, fifth, and the sixth sets is 3, 4, 5, 6, 7, 8 successively.

(iv) the researcher added one more irrelevant item or shape (which is put in for confusion) in one figure of each set except the second set which added one more irrelevant item in two of them.

(v) the irrelevant item appeared in the compound form of figures but not in the discrete form of them.

The assignment of subjects' performance in this test is to be found in appendix 2(b) as extracted from Johnson, [46].

Furthermore, the figure intersection test scoring is allocated in appendix 2(c).

3.3 The Procedure employed

The procedure which employed includes the following:

3.3.1 Student sample

In 1986 when the first term of university started, the researcher sampled a number of first year biological students who had incorporated the subject of chemistry in their courses.

The research began by applying the digit backward test (DBT) and the figure intersection test (FIT) on 177 students. The objective of using these tests was to measure the holding/thinking space (X) of students in order to compare that with their performance in chemistry examinations.

The performance of students in DBT and FIT is shown in table 1. The sample is composed of the students;

(i) who obtained the same score in DBT and FIT.

(ii) who obtained minus or plus 1 (when compared with DBT). Almost all those students obtained minus 1 in FIT (FIT requires much more effort than DBT).

(iii) who sat only one test of the two.

Table 1

A comparsion of students scores in DBT & FIT tests

Performance between DBT and FIT scores	Number of students
Identical score	45
Differences plus or minus 1	64
Attendance in one test only	42
Differences › plus or minus 1	26 *
Total	177

* These were eliminated from the rest of the study.

The sample of 151 students was subdivided into groups according to the students' holding/thinking space as shown in table 2.

Table 2

The groups of holding/thinking space

X-space groups	No. of students
X - 5	60
X - 6	45
X - 7	46
Total	151

3.3.2 How to find out the Z-demand of the questions

According to the hypothesis, the Z-demand represents the maximum number of thought steps in the question (problem) taken by the weakest students who successfully solved the problem. Z-demand will vary with students previous knowledge of how they have taught. Thus the method of using the students to 'calibrate' the demand is employed.

The researcher analysed the complexity of questions of -first year- chemistry examinations during all terms of 1987. He then made a comparison between the performance of the sample in these questions and their previous psychological tests' scores of holding/thinking space.

3.4 Theoretical prediction from the model

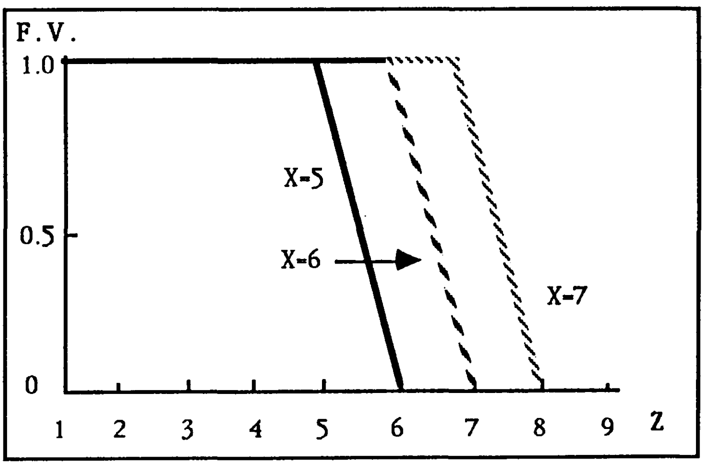


Figure 3.1 Expected performance of pupils with values of X as demand increases.

Johnstone and El-Banna expected [42] an ideal curve as shown in figure 3.1 for the performance of students according to their capacities. They expected that the student with capacity X=5 will perform well if the Z-demand of a question is equal or less than

5, but his performance will decline rapidly if the Z-demand of a question exceeds 5. Similarly, the same situation could happen for the students of X=6 and X=7.

3.5 January examination

In the January 1987, ordinary chemistry class examination 6 questions were analysed. The Z-demand of questions were 4, 5, 7, 8, 9, 14. The analysis of questions into thought steps was obtained from both teachers and students

The following examples explain the way in which the questions were analysed:

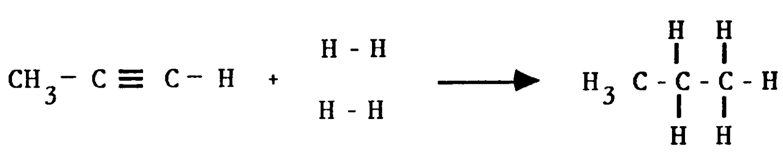
Q. Using the bond energies below, calculate the enthalpy change for the reaction

$$CH_3C \equiv CH + 2H_2\,(g) \longrightarrow CH_3\,CH_2\,CH_3\,(g)$$

Propyne Propane

C – C	348 kJ mol^{-1}
C ≡ C	837 " "
C – H	412 " "
H – H	436 " "

This question could be analysed into the following number of thought steps:



Propyne Propane

Step 1. Break the triple bond of propyne and break the bonds of hydrogen.

Step 2. Make four bonds between C - H, and one between C - C.

Step 3. Calculate the enthalpy of broken bonds.

$$(+837) + 2(436) = 1709 \text{ kJ mol}^{-1}$$

Step 4. Calculate the enthalpy of formed bonds.

$(348) - 4\,(412) = 1996$ kJ mol^{-1}

Step 5. Calculate the enthalpy differences by applying the following equation

ΔH = total formed bonds + total broken bonds

$= (1709) - (1996)$ kJ mol^{-1}

$= - 287$ kJ mol^{-1}

Therefore the Z-demand of this question is equal to 5 (thought steps).

Q. At 27^{o} C, the enthalpy change for the graphite $\rightarrow$ diamond transition is 1.9 kJ mol^{-1} and the entropy change is - 3.3 J K^{-1} mol^{-1}. What is the spontaneous direction of the transition at 27^{o} C ?

The thought steps of this question are

Step 1. Recall the equation

$\Delta G = \Delta H - T\Delta S$

In which you need to calculate ΔG.

Step 2. In order to calculate ΔG, change the value of T to kelvin

$27 + 273 = 300$ K

Step 3. Remember to change ΔS to kJ K^{-1} mol^{-1}

(divide by 1000)

Step 4. Substitute values into the equation

$\Delta G = 1.9 + 300\,(3.3 / 1000)$ kJ/mol

$= 2.9$ kJ mol^{-1}

Step 5. Remember that ΔG = -ve for a process to occur spontaneously.

Step 6. Recognise that if ΔG = +ve the reverse reaction will change the sign of ΔG and so will occur i.e diamond $\rightarrow$ graphite.

Therefore the Z-demand of this question is equal to 6 (thought steps).

The analysis of the other questions of the January examination is to be found in appendix 3.

The result which was obtained from the performance of the sample in the January examination did not conform exactly to the idealised curves of figure 3.1, but there are several similarities.

The Z-demand of questions was distributed from 4 to 14 and no question was found of Z=7, therefore the researcher expected that the students of X=7 would not be able to exhibit any superiority over those students of X=6. Moreover, no question was found of Z=10 to Z=13.

Table 3

The F.V. for each question of the January examination related to students capacities

Questions / Groups	Q1 Z = 4	Q2 Z = 5	Q3 Z = 6	Q4 Z = 8	Q5 Z = 9	Q6 Z = 14
X = 5 (N = 60)	0.95	0.40	0.42	0.20	0.03	0
X = 6 (N = 45)	0.93	0.40	0.38	0.22	0.02	0
X = 7 (N = 46)	0.93	0.59	0.41	0.24	0.02	0

The facility value for each question related to students' capacities is shown in table 3. The facility value represents the number of students who answered perfectly divided by the number of students who composed of the group in the sample.

The researcher then tried to find out whether the students' holding/thinking space significantly influenced their ability in solving these questions of various complexity (demand) so he applied the method which recommended by Kellet [47] as shown in appendix 4. From this method, a comparison was made for each question between the students' groups of different holding/thinking space and obtained the result which is displayed in table 4.

The X=7 students are assumed to start declining after Z exceeds 7 but the performance of students decreases after Z exceeds 6 since no question of Z=7 was found thus the curve began declining after Z exceeds 6. It is possible to notice that some of X=7 students still survive at Z=9 presumably as a result of employing particular strategies but no one was able to succeed at Z=14. The X=7 students performance is shown in figure 3.2.

Table 4

The significance of the F.V. differences for each question of the January examination between the students' groups.

Questions \ Group differences		X-5 & X-6	X-6 & X-7	X-5 & X-7
Q1	Z - 2	N. S	N. S	N. S
Q2	Z - 3	N. S	N. S	N. S
Q3	Z - 4	N. S	N. S	N. S
Q4	Z - 5	N. S	N. S	N. S
Q5	Z - 6	N. S	N. S	N. S
Q6	Z - 7	N. S	N. S	N. S
Q7	Z - 9	N. S	N. S	N. S

The performance of X=6 students starts dropping down slightly at Z=5 and rapidly at Z=6 but may still survive at Z=8 and Z=9 according to their particular strategies, however, they failed at Z=14. The curve for X=6 students is shown in figure 3.3.

Those students of X=5 behaved slightly differently from the rest, they seemed to employ as much strategy as was possible for them and managed to perform quite well at Z=6 and even better than the students of X=6 and X=7 but their performance declined more at Z=8 than the other students and some still survived at Z=9 but then dropped to zero like the others at Z=14. The X=5 students are shown in figure 3.4.

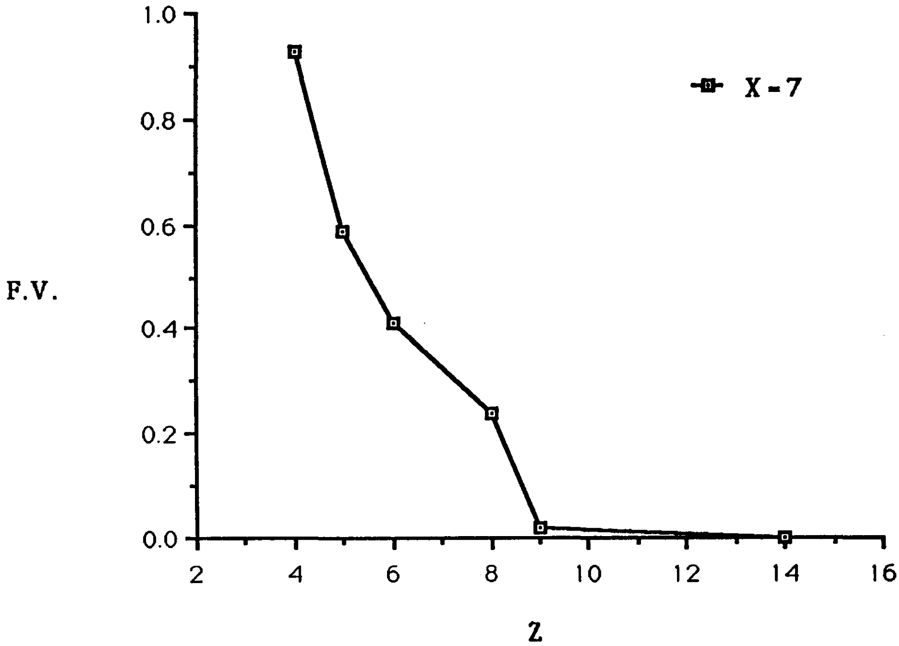


Figure 3.2 The performance of X=7 students in the January examination.

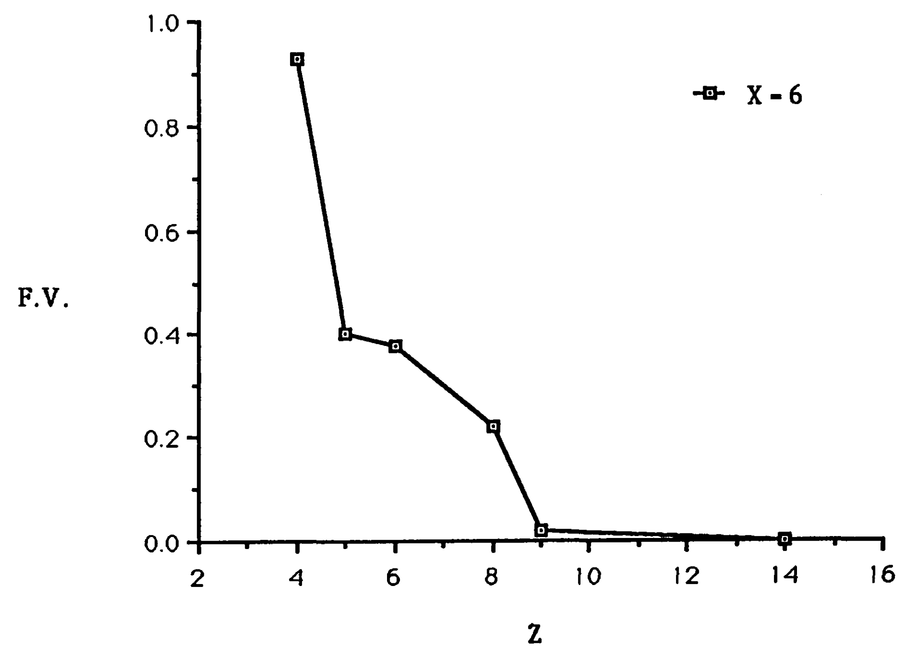


Figure 3.3 The performance of X=6 students in the January examination.

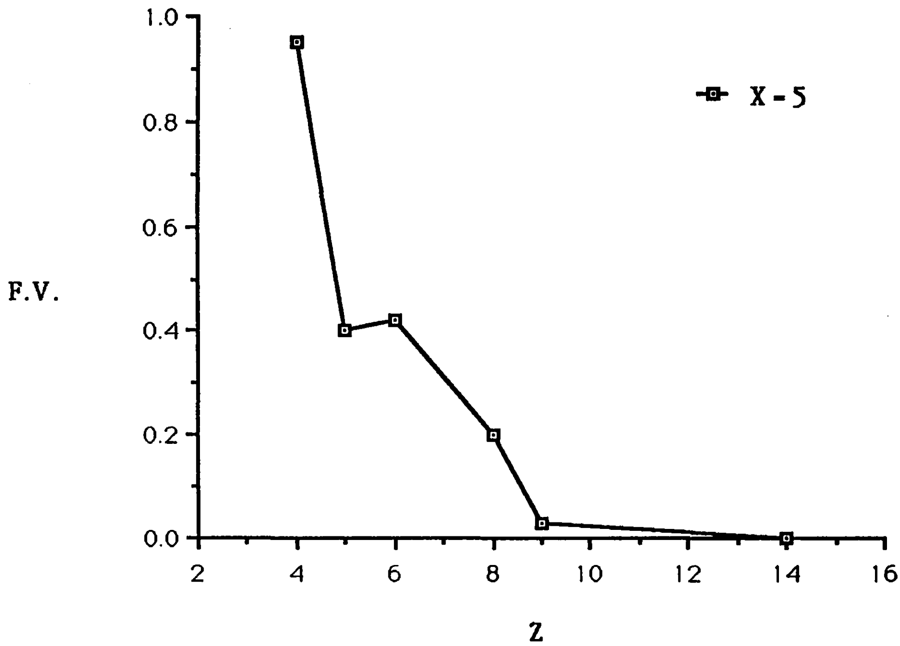


Figure 3.4 The performance of X=5 students in the January examination.

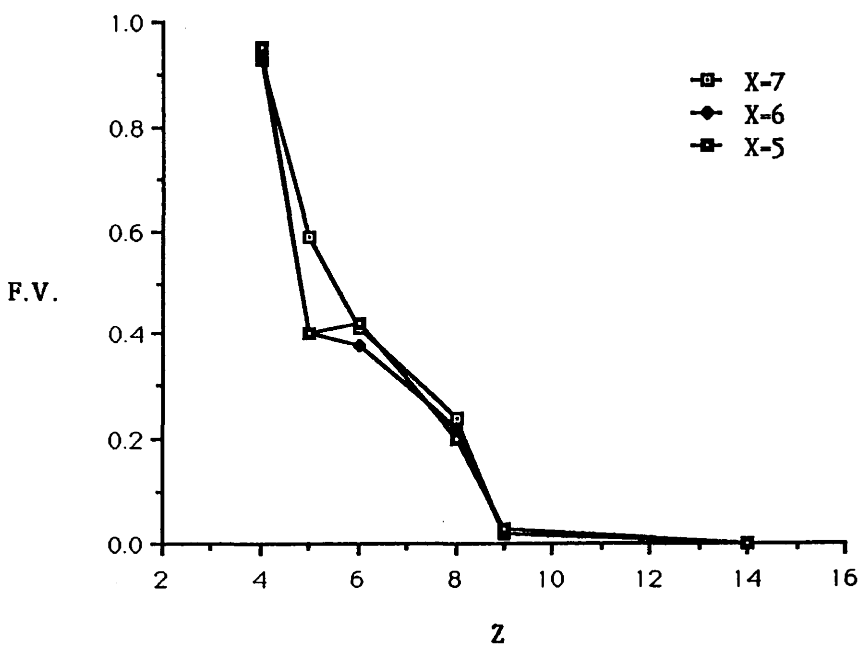


Figure 3.5 The performance of the whole sample in the January examination.

The curves of all groups together in the January examination are shown in figure 3.5.

There is no discrimination in performance apparent for students of different X-capacities. It is important to state that the result of the January examination is not typical since the sample comprises of biology students who, in general, gave a rather mundane performance in the chemistry examination. Moreover, the sample has a tendency to have low scores in most questions (the facility value was equalled to 0.4 or less) therefore discrimination in the performance between the three groups was not apparent.

However, strategy seems to be the determining factor in the way in which the individual will solve his problems.

The hypothesis assumes that the students acquire strategies from various sources and the teacher is considered to be one of these sources. He can always help and encourage students to develop their strategies so that the students can solve tasks which are demanding by relying on their most powerful strategies.

An interview was conducted which clarifies the strategy process. Eight of the X=5 students were selected as they achieved better than their capacity limitation would suggest. The general strategies which were identified by the interview are;

(i) drawing a graph whenever data is presented in a column or row form.

(ii) checking each maths operation to see if the order of magnitude of the answer seemed to be correct.

(iii) identifying a suitable equation to use.

(iv) practicing working out some sample problems during studying.

(v) summarising, condensing and reorganising lecture notes in the process of studying.

(vi) for a problem using an organic chemical formula the student wrote out the complete structural formula before beginning.

(vii) underlining answers to parts of problem and important parts of the problem as a mnemonic device.

(viii) attempting to use units associated with the numbers in the problem as clue for solving the problem.

Most of those students seemed to be consciously aware of using some or all of these strategies.

3.6 April examination

Following the same methods, the same sample of students was assessed in the next examination in order obtain more data about their achievement. Therefore, the chemistry answer papers of the April examination were collected and the questions were analysed into numbers of thought steps.

Eight questions were analysed for Z-demand, as shown in appendix 5. The Z-demand of questions was distributed from 2 to 8 and no question was found of Z=3. Four students did not attend this exam, one from the X=5 group and three from the X=7 group. The facility value for each question versus the students capacities is shown in table 5.

Table 5

The F.V. for each question of the April examination over related to students capacities

Questions / Groups	Q1 Z - 2	Q2 Z - 4	Q3 Z - 5	Q4 Z - 5	Q5 Z - 6	Q6 Z - 7	Q7 Z - 8	Q8 Z - 8
X - 5 (N - 59)	0.80	0.73	0.52	0.66	0.51	0.30	0.22	0.13
X - 6 (N - 45)	0.71	0.71	0.60	0.69	0.56	0.51	0.33	0.17
X - 7 (N - 43)	0.77	0.75	0.56	0.72	0.42	0.39	0.33	0.19

A comparison was made for each question between the students' groups to find out whether the students holding/thinking space significantly influenced their ability in solving questions. Table 6 shows that, no significant value was found for the facility of each question except the question number 6 of Z=7 exhibits a significant value at 5% level.

The three curves of the groups were plotted together and the final pattern which emerged is shown in figure 3.6.

Table 6

The significance of the F.V. differences for each question of the April examination between the students' groups.

Questions \ Group differences	X-5 & X-6	X-6 & X-7	X-5 & X-7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 4	N. S	N. S	N. S
Q3 Z = 5	N. S	N. S	N. S
Q4 Z = 5	N. S	N. S	N. S
Q5 Z = 6	N. S	N. S	N. S
Q6 Z = 7	S *	N. S	N. S
Q7 Z = 8	N. S	N. S	N. S
Q8 Z = 8	N. S	N. S	N. S

* At 5% level

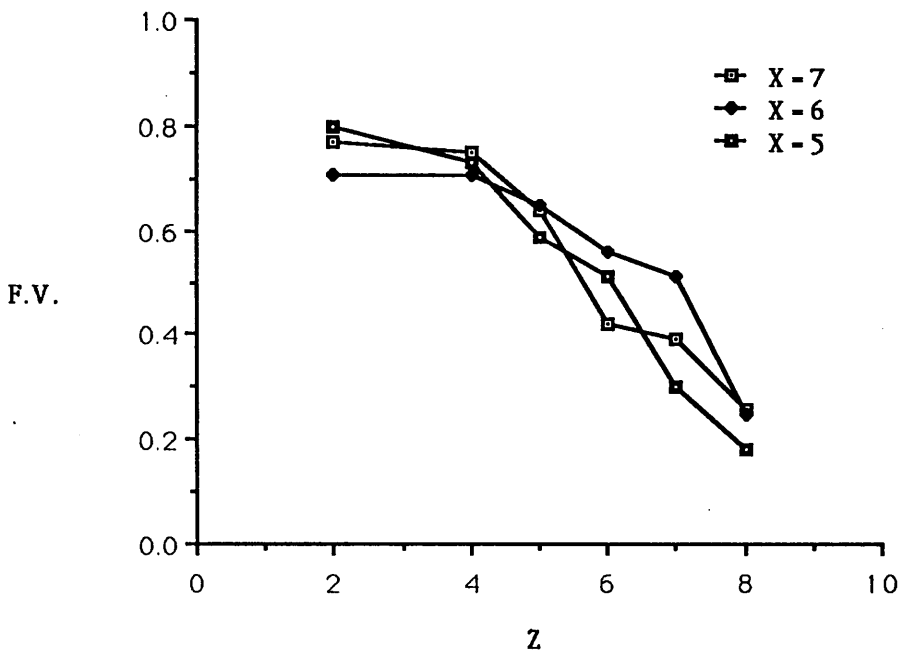


Figure 3.6 The performance of the whole sample in the April examination.

As is shown above, the X=5 students performed very well at the beginning and even better than other groups, and they managed to perform well even when the Z-demand exceeded their capacity at Z=6, but their performance declined rapidly after that.

The performance of the X=6 students, who are positioned between the two other groups, began to decline rapidly after the Z-demand exceeded 6.

The X=7 students behaved in a different way, they declined gradually with the increase in complexity of the tasks till Z=6, but they make a temporary recovery at Z=7, then decline again rapidly.

The whole sample still survived after the Z-demand exceeded the capacity of the students which indicates that the students individually used a type of strategy to solve their problems. That would explain the fact that the groups did not drop to zero even when Z > X. However, the sharp fall in performance still increases with the complexity of the tasks (Z-demand).

3.7 Exempt students

In May 1987, new data was incorporated into the research when the chemistry department assessed and classified students, according to the practice of Glasgow University, into two categories; the students who were exempt from the June examination as they achieved efficiently in the January and April examinations and obtained remarkable scores, and the students who were not.

In comparison with capacity groups, it was found that 7 students of X=5, 8 students of X=6, and 10 students of X=7 were exempt from the June examination. Table 7 shows the number and percentage of those students.

Furthermore, it was found that the group of X=7 students achieved better than the others in the examinations and the mean scores of them in the variety of questions (various demands) are greater than the rest of the sample which reflects their superior ability in solving problems. In brief, if more questions are available to the X=7 students they could handle efficiently more materials in their big X-space than the others so they would get the higher scores and be more likely to be exempt.

Table 7

The exempt students from the June examination 1987

Groups	No. of exemption	%
X = 5 (N = 60)	7	11.6
X = 6 (N = 45)	8	17.7
X = 7 (N = 46)	10	21.7

To find out whether the numbers of the exempt students as shown in table 7 are significant, the researcher applied Chi-square test [48] as following:

$$\sum X^2 = \sum \frac{(O - E)^2}{E}$$

O - The Observed frequency

E - The Expected frequency

X^2 - The Chi-square value

1 - Calculate the Expected frequency of the X=5, X=6, and X=7 exempt students.

$$\text{The Expected frequency} = \frac{\text{The group's number}}{\text{The number of all the sample}} \times \text{The number of all exemption}$$

$$\frac{60}{151} \times 25 = 10 \quad \text{For the X=5 students}$$

$$\frac{45}{151} \times 25 = 7.5 \quad \text{For the X=6 students}$$

$$\frac{46}{151} \times 25 = 7.5 \quad \text{For the X=7 students}$$

2 - The Observed frequency is

7 For the X=5 students

8 For the X=6 students

10 For the X=7 students

3 - Application

$$\sum X^2 - \frac{(7 - 10)^2}{10} + \frac{(8 - 7.5)^2}{7.5} + \frac{(10 - 7.5)^2}{7.5}$$

$$= 0.9 + 0.03 + 0.83$$

$$= 1.76$$

The degrees of freedom are 2

The result is significant at 20% level.

Therefore it is possible to reject the null hypothesis at 20% level.

Furthermore, the researcher tried to find out whether there is any significant correlation between the numbers of the exempt students in every two groups so he applied the Chi-square again and obtained the result which is shown in table 8. The best significant correlation is found between the X=5 students and the X=7 students.

Table 8

The significant differences between the students' exempt groups

Groups	Chi-square	Value
X = 5 & X = 6	Not significant	–
X = 6 & X = 7	Not significant	–
X = 5 & X = 7	Sig. at a 10% level	3.55

3.8 June Degree examination

In June 1987, the students who had not been exempted were examined again. The question sheet of the chemistry examination was analysed and 7 questions were found of Z-demand between 2 to 9 thought steps, but no question involving Z=8 existed. The analysis of the June questions into number of thought steps is to be found in appendix 6.

Two students of X=7 and one of X=5 did not attended the examination. Table 9 shows the number of students who were examined and the facility value.

Table 9

The F.V. for each question of the June examination versus the students' capacities

Questions / Groups	Q1 Z=2	Q2 Z=3	Q3 Z=4	Q4 Z=5	Q5 Z=6	Q6 Z=7	Q7 Z=9
X = 5 (N = 51)	0.80	0.51	0.50	0.41	0.36	0.27	0.02
X = 6 (N = 37)	0.73	0.47	0.48	0.35	0.44	0.30	0.03
X = 7 (N = 31)	0.84	0.48	0.42	0.39	0.35	0.26	0.04

It is possible to see from the table that there is no discrimination between the groups since the best students have been removed. However, no significant value was found for the facility value of each question of the June examination between the students' groups as shown in table 10.

The final pattern which emerged when the three curves were superimposed is shown in figure 3.7.

Table 10

The significance of the F.V. differences for each question of the June examination between the students' groups.

Group differences / Questions	X=5 & X=6	X=6 & X=7	X=5 & X=7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	N. S	N. S	N. S
Q5 Z = 6	N. S	N. S	N. S
Q6 Z = 7	N. S	N. S	N. S
Q7 Z = 9	N. S	N. S	N. S

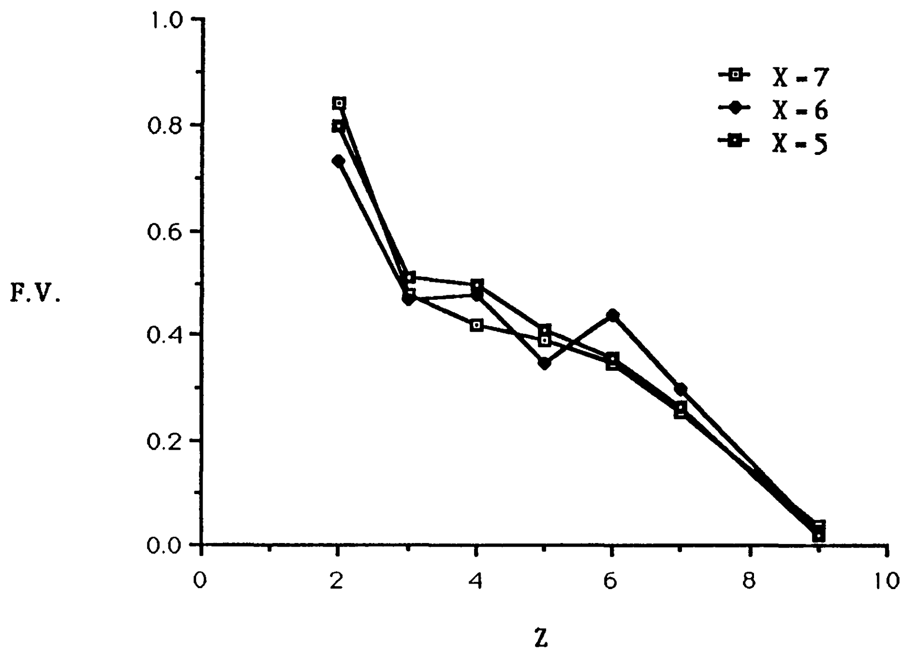


Figure 3.7 The performance of the whole sample in the June examination

The pattern in figure 3.7 exhibits no big differences in the performance between the groups. The curves seem to be identical and declined simultaneously. The interpretation of this identical performance is again related to the exempt students who have been removed.

Generally, this result has revealed what is unusual about the attainment of the students in the examination. The group of X=5 would appear to be the best group and the group of X=7 appear to be the worst.

As mentioned, the unexpected curves which appeared were due to the number of students who were exempt from the June examination but whether this interpretation has any reality or not, the researcher suggests an estimated performance for those students who were exempt from the June examination and he added them to the June sample assuming them to obtain full marks in their answers.

The facility value which emerged from the estimated curves is shown in table 11. The pattern revealed from this is shown in figure 3.8.

Table 11

The F.V. for each question of the June examination versus the students capacities (including students who were exempt)

Questions / Groups	Q1 Z=2	Q2 Z=3	Q3 Z=4	Q4 Z=5	Q5 Z=6	Q6 Z=7	Q7 Z=9
X = 5 (N = 58)	0.82	0.57	0.56	0.48	0.44	0.36	0.14
X = 6 (N = 45)	0.78	0.56	0.57	0.47	0.54	0.42	0.20
X = 7 (N = 41)	0.88	0.61	0.56	0.54	0.51	0.44	0.27

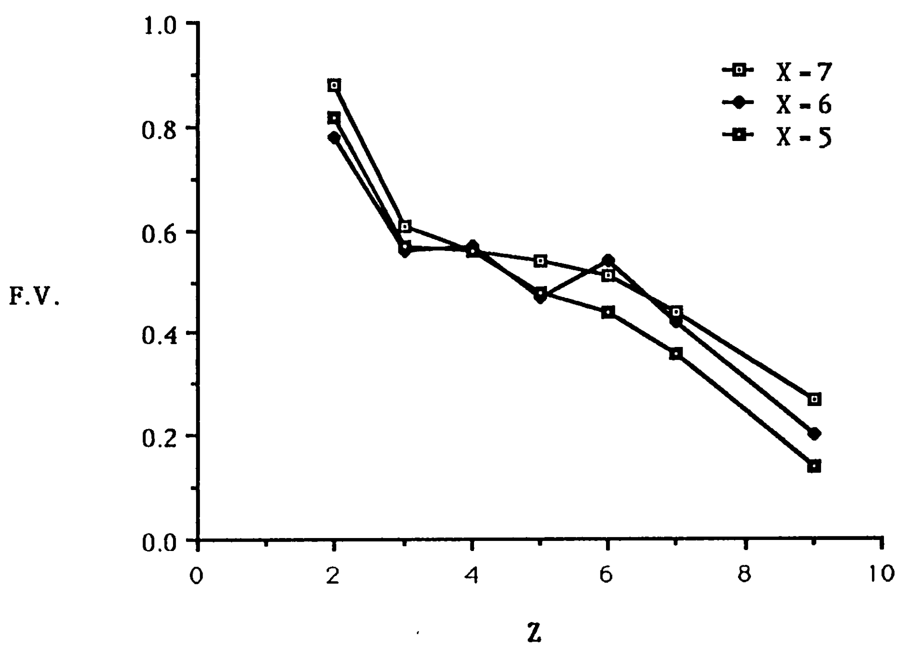


Figure 3.8 The estimated performance of the whole sample (after adding the student who were exempt) in the June examination.

It shows that the number of exempt students affected the final result. Whereas the X=7 students had shown unexpectedly by low attainments in figure 3.7, they behave rationally after the number of exemptions have been added in figure 3.8. It is possible to distinguish between the performance of X=7 students which was obtained from the two figures, in particular, at the area between Z=3 to Z=7. The performance of the X=5 and X=6 students is altered also and their achievement are similar, specifically at lower demands as would be expected.

3.9 A combination of the chemistry examination results for January and April

It seems to be reasonable to combine the results obtained from the sample of university students 1986-1987 on the basis of demand.

Accordingly, the facility value for each question in all the examinations has been considered in order to determine the average performance of students in questions of the same demand. The Z-demand of the questions is distributed between Z=2 to Z=14 and there is no question found of Z=10 to Z=13. The mean score of facility value is shown in table 12.

Table 12

The mean score of the facility value for the attainment of university students 1986-1987

Questions / Groups	Q1 Z=2	Q2 Z=3	Q3 Z=4	Q4 Z=5	Q5 Z=6	Q6 Z=7	Q7 Z=8	Q8 Z=9	Q9 Z=14
X = 5	0.80	0.51	0.62	0.53	0.44	0.29	0.18	0.02	0
X = 6	0.72	0.47	0.60	0.55	0.50	0.40	0.25	0.03	0
X = 7	0.81	0.48	0.59	0.56	0.39	0.33	0.26	0.04	0

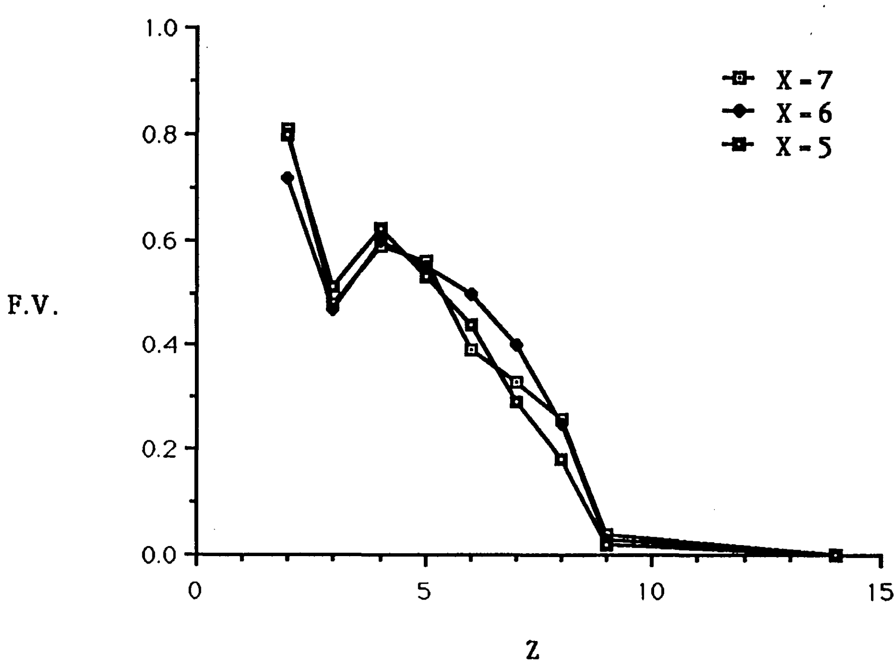


Figure 3.9 A comparison of the examinations (January & April).

The pattern in which emerges from a comparison of the examinations is shown in figure 3.9. The curves of X=5, X=6, and X=7 students are shown separately in appendix 7.

3.10 The general S - shaped curve results

Generally the students begin to decline gradually from Z=4 onwards. But the X=7 group achieved more than other groups at high demand questions.

The X=6 students performed in a similar way to the students of X=7, their gradual decline began at Z=4 but became more precipitate at Z=7. This group seems to have performed better than other groups at Z=6 and Z=7.

The X=5 students declined rapidly after the Z-demand exceeded their capacity. Students of this group seem to display their attainments more clearly than other groups.

CHAPTER FOUR

The hypothesis applied to tertiary and secondary levels of chemistry 1987-1988

4.1 A new sample of university students

Following the procedures described for the research, in 1987, another sample of chemistry students was selected from the first year chemistry students of Glasgow university.

The students' holding/thinking space was measured and then their progress in the chemistry examinations was traced from the beginning of the first term till the end of the last term in 1988, using and comparing their performance in chemistry with their assessed holding/thinking space.

Two types of psychological tests were employed for assessing the capacity of students; the digit backward test (DBT) which is explained in Chapter 3 and the letter test (LT).

4.2 The letter test (LT)

It is another memory span test which uses a visual method as a means of measurement. The letter test relies on showing subjects a set of letters which has been randomly chosen and which the subject should retain and write in reverse order.

The test sheet is similar to that of the digit backward test. The design of the letter test sheet is to be found in appendix 8.

The test is begun by showing the subject two letters and ends by showing him eight letters (two times per set). Each sequence of letters should be;

(i) visible for about one second per letter on the screen of the overhead projector.

(ii) written down by the subjects in a similar time (after the screen has been covered).

The marking of this test is analogous to the marking of the digit backward test, and the marker would accept again one correct answer from the two rows.

4.3 students selection

At the beginning of the first term, the researcher applied the digit backward test (DBT) to the sample of 251 students and after a few days he then applied the letter test.

Table 13

Students' scores in LT only

Performance in the letter test	Number of students
Identical score with DBT	8
+ 1 than the DBT	15
- 1 than the DBT	3
Differences › ± 1	5
Attendence LT test only	2
Total	33

Table 14

A comparsion of students scores in DBT & LT tests

Performance between DBT and LT scores	Number of students
Identical score	8
Differences plus or minus 1	18
Attendance in DBT only	251
Attendence in LT only	2
Differences › plus or minus 1	5 *
Total	284

* These were eliminated from the rest of the study.

(LT) to some of them (33 students) to test the feasibility of it. The objective of these psychological tests, as mentioned, was to measure the holding/thinking space of the students. Table 13 and 14 show the performance of the students in these tests.

The experimental sample is composed of the students;

(i) who obtained identical scores in DBT and LT.

(ii) who obtained plus or minus 1. When compared LT with DBT almost all students obtained minus 1 in DBT hence DBT needs more effort than LT. Subsequently, the researcher used the higher digit score when he matched between the two scores obtained from both DBT and LT for the same student.

(iii) who sat only one test of the two.

The total number of the sample is 279 and can be subdivided into three groups according to the students' holding/thinking space as shown in table 15.

Table 15

The groups of holding/thinking space

X-space groups	No. of students
X = 5	96
X = 6	76
x = 7	107
Total	279

4.4 The January examination

In January 1988, the sample was examined and the question sheet of the first year chemistry class examination showed that 6 questions had demands which were distributed from 4 to 9.

The analysis of these questions into thought steps is to be found in appendix 9. Three students of the X=5 and two students of the X=7 did not attend. The facility value for each question versus the students' capacities is shown in table 16.

Table 16

The F.V. for each question of the January examination versus students capacities

Groups \ Questions	Q1 Z = 4	Q2 Z = 5	Q3 Z = 6	Q4 Z = 7	Q5 Z = 8	Q6 Z = 9
X = 5 (N = 93)	0.67	0.45	0.34	0.22	0.16	0.07
X = 6 (N = 76)	0.67	0.49	0.50	0.29	0.24	0.13
X = 7 (N = 105)	0.77	0.51	0.43	0.34	0.26	0.10

Table 17

The significance of the F.V. differences for each question of the January examination between the students' groups.

Questions \ Group differences	X=5 & X=6	X=6 & X=7	X=5 & X=7
Q1 Z = 4	N. S	N. S	N. S
Q2 Z = 5	N. S	N. S	N. S
Q3 Z = 6	S *	N. S	N. S
Q4 Z = 7	N. S	N. S	N. S
Q5 Z = 8	N. S	N. S	N. S
Q6 Z = 9	N. S	N. S	N. S

* At 5% level.

A comparison was made for each question between the students' groups to determine whether the students' capacities significantly influenced their attainments in the questions. Table 17 shows this.

The pattern which emerges from the performance of the sample according to their capacities is shown in figure 4.1.

The questions seem not to have demands of less than 4 therefore the X=5 students declined rapidly during their performance but some still survived at Z=9.

The performance of the X=6 students was quite good but declined rapidly after Z exceeded their capacity.

The X=7 students, in general, performed better than the other two groups and their performance declined gradually from Z=5 to Z=8 and then rapidly at Z=9.

It is apparent that the declination in performance for the X=6 group when the Z-demand exceeds the students' capacity seems to be clearer than the others.

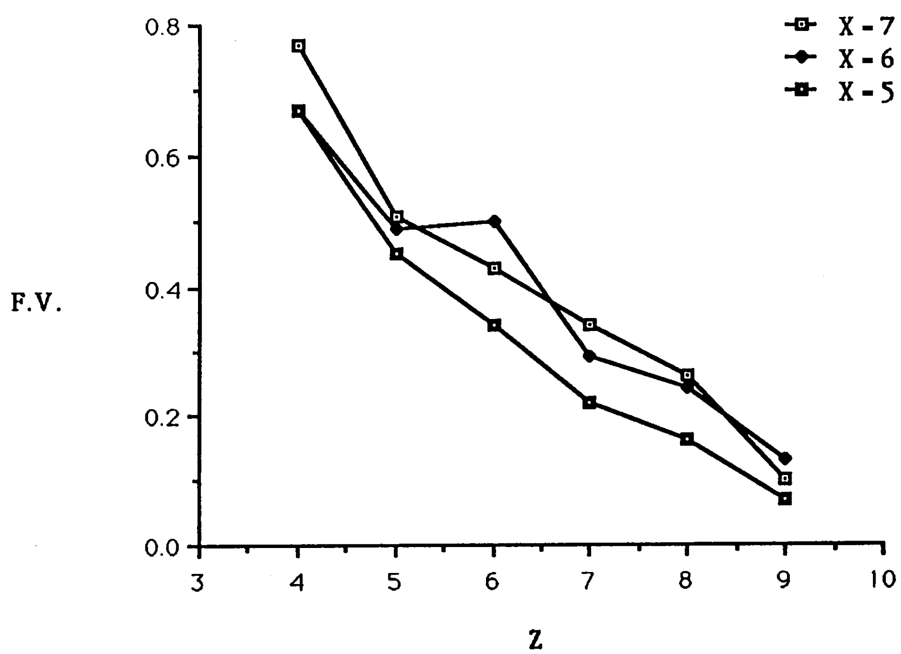


Figure 4.1 The performance of the sample in the January examination

4.5 The April examination

As soon as the students finished their exam in April, the questions were analysed to determine the number of thought steps involved in each.

Table 18

The F.V. for each question of the April examination versus students capacities

Groups \ Questions	Q1 Z = 2	Q2 Z = 3	Q3 Z = 4	Q4 Z = 5	Q5 Z = 6	Q6 Z = 7	Q7 Z = 8	Q8 Z = 9
X = 5 (N = 87)	0.84	0.78	0.56	0.44	0.21	0.11	0.09	0.07
X = 6 (N = 72)	0.83	0.85	0.53	0.31	0.30	0.19	0.14	0.08
X = 7 (N = 104)	0.88	0.81	0.54	0.42	0.27	0.25	0.16	0.16

Table 19

The significance of the F.V. differences for each question of the April examination between the students' groups.

Questions \ Group differences	X-5 & X-6	X-6 & X-7	X-5 & X-7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	S***	N. S	N. S
Q5 Z = 6	N. S	N. S	N. S
Q6 Z = 7	N. S	N. S	S*
Q7 Z = 8	N. S	N. S	N. S
Q8 Z = 9	N. S	N. S	N. S

* At 5% level. *** At 10% level.

It was found that 8 questions had demands distributed from 2 to 9 as shown in appendix 10. The facility value for each question is exhibited in table 18.

The researcher lost 16 students from his sample; 9 students of X=5, 4 students of X=6, and 3 students of X=7, as, for various reasons, they did not attend the April examination.

Furthermore, the significance of the facility value differences for each question between the students' groups is shown in table 19.

The pattern which emerges from the performance of the whole sample in this examination is shown in figure 4.2.

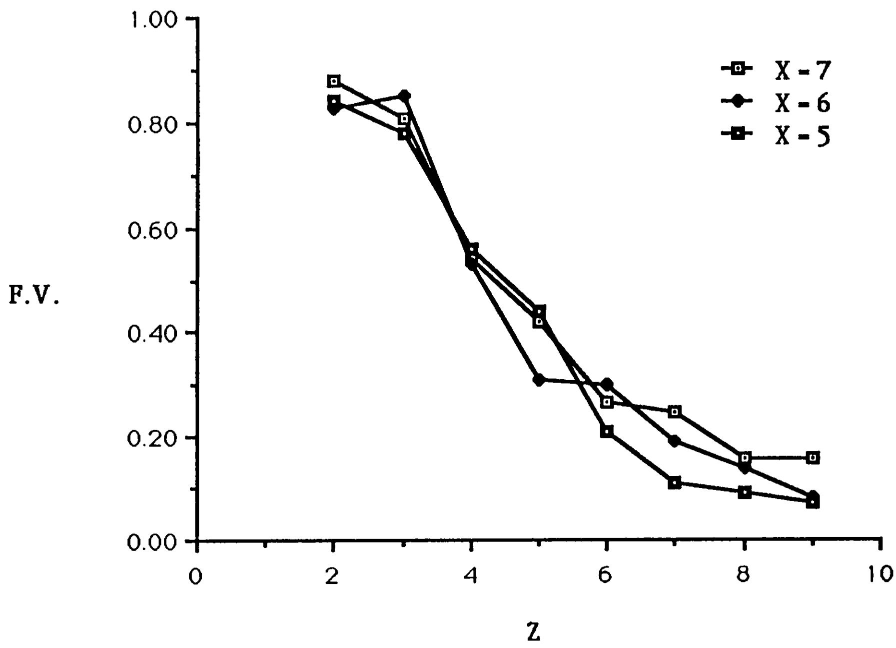


Figure 4.2 The performance of the sample in the April examination.

The X=5 students performed well at the beginning and even better than the X=6 students and the X=7 students at Z=4 and Z=5 but they plunged to the lowest position after Z-demand exceeded their capacity.

Although the X=6 students achieved much at the beginning, they started to decline abruptly after Z=3 then performing better than the other groups at Z=6 but declining again after that.

The X=7 students declined rapidly after the Z-demand exceeded 7, however they seemed to achieved more than the others as expected at Z=9 which indicated their greater capacity than the rest of the students to survive at high demand questions.

Generally, it is possible to detect three points which repeatedly emerge from drawing the curves of students' performance;

(i) the students who have lower capacities seem to compete well with others in performance at the lower demand questions like Z=2, 3, and 4. These students ,sometimes, may even perform better than others.

(ii) there is a substantial decline in the performance of all students after the Z- demand exceeds their capacity.

(iii) the ability of high capacity students to survive at high demand questions seems to be the greatest, therefore, the last student who may fail in the highest demand question may be assumed to belong to the group of high capacity students.

4.6 Exempt students

According to the practice of the Glasgow University, a student may be exempt from attending the June examination if he achieves high marks in the January and April examinations. Therefore the researcher devised a means by which to incorporate experimental work involving these students.

In comparison with the other capacity groups, it was found that 18 students of X=5, 26 students of X=6, and 40 students of X=7 were exempt from the June examination. These numbers are shown in table 20.

Table 20

The exempt students from the June examination 1988

Groups	No. of exemption	%
X = 5 (N = 96)	18	18.75
X = 6 (N = 76)	26	34.21
X = 7 (N = 107)	40	37.38

To find out whether these results are significant or not, the Chi-square test was applied as following:

$$\sum X^2 = \frac{(O - E)}{E}$$

$$= \frac{(18 - 29)^2}{29} + \frac{(26 - 23)^2}{23} + \frac{(40 - 32)^2}{32}$$

$$= 4.17 + 0.39 + 2$$

$$= 6.65 \text{ Chi-square value}$$

The degree of freedom = 2

The result is significant at a 5% level

Therefore it is possible to reject the null hypothesis at the 5% level. The null hypothesis means that the differences between numbers are not due to chance[47].

E - The expected frequency

O - The observed frequency

X^2 - The Chi-square value

Table 21
The significance of exemptions over the students' groups

Groups	Chi-square	Value
X = 5 & X = 6	Sig. at a 5% level	3.95
X = 6 & X = 7	Not significant	–
X = 5 & X = 7	Sig. at a 2% level	6.13

A comparison was made between the number of exemptions in the groups, to find out whether these numbers have any meaningful frequency, table 21 shows this comparison.

The researcher ignored the June examination as he realised that the large number of exempt students would affect the attainment of each group of the sample and would reveal unusual curve patterns as occurred in the previous chapter.

4.7 A combination of the results for the January and April examinations

The results of both the January and April examinations were combined to assess the average performance of the students in questions of the same demand.

The facility value of questions was distributed from Z=2 to Z=9. The mean score of the facility value is shown in table 22.

Moreover, the pattern which emerges from this combination is shown in figure 4.3 and the curves of the X=5, X=6, and X=7 groups are shown separately in appendix 11.

Table 22

The mean score of the F.V. for the attainment of chemistry students 1987-1988

Groups \ Questions	Q1 Z = 2	Q2 Z = 3	Q3 Z = 4	Q4 Z = 5	Q5 Z = 6	Q6 Z = 7	Q7 Z = 8	Q8 Z = 9
X = 5	0.84	0.78	0.62	0.45	0.28	0.17	0.13	0.07
X = 6	0.83	0.85	0.60	0.40	0.40	0.24	0.19	0.11
X = 7	0.88	0.81	0.66	0.47	0.35	0.30	0.21	0.13

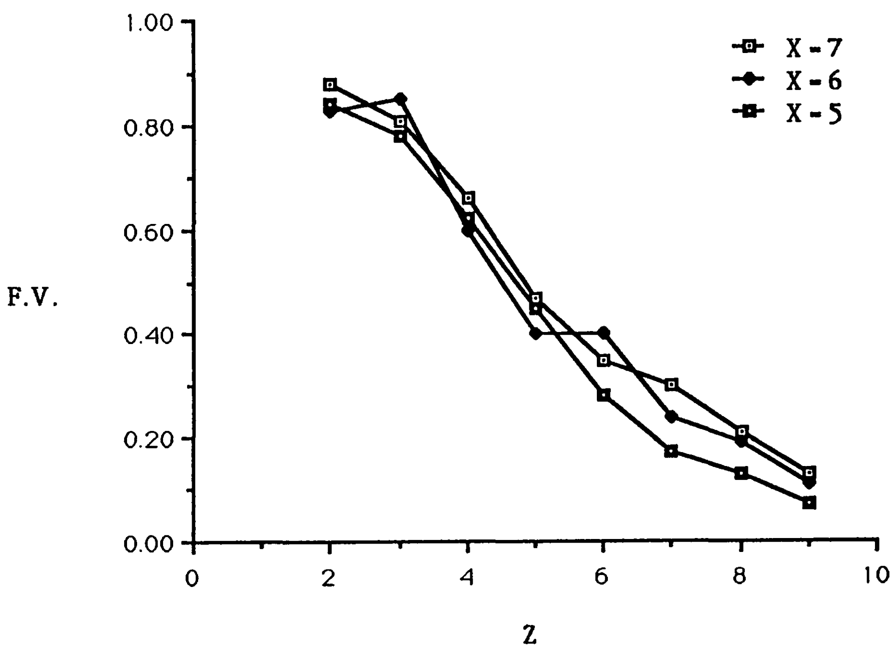


Figure 4.3 The combined performance of the sample in the January and April examinations.

The combination revealed a clear decline in each curve as demand increases and there was some similarity to the idealised curves of the hypothesis.

Individually, the X=5 students drop down rapidly starting from Z=3 but some still survive at Z=9.

The rapid declination in performance of the X=6 students when the Z-demand exceeds their capacity seems to be exhibited more clearly than the others.

The X=7 students showed the highest attainment and retained the largest number of survivors at Z=9.

4.8 The general attainment of the university sample

As shown, the research sample was traced for a whole year after it had been divided it into three groups in terms of the holding/thinking space of the students.

It is reasonable to emphasise that the sample, in general, performed in the examinations in a manner which conformed to the students capacities, in other words, the students' performance was in accordance with the hypothesis.

Additionally, the mean score of the examinations revealed that the X=7 students have the ability to obtain high scores and to do better than other students. The mean score of the X=6 students lay between the mean scores of the X=5 and X=7 students.

4.9 A sample from secondary schools

In late 1987, a new sample was chosen from four secondary schools in Scotland. These were Hucheson's Grammar School (Glasgow), Graeme High School (Fulkirk), Trinity High School (Renfrew), and Stirling High School.

The pupils selected were the O' Grade pupils or the fourth year pupils who had studied chemistry since the third year of the secondary school. The total number of pupils were 282 and were distributed as follows;

(i) 64 pupils from Graeme High School.

(ii) 49 pupils from Trinity High School.

(iii) 126 pupils from Hucheson's Grammar School.

(iv) 43 pupils from Stirling High School.

The researcher intended to repeat the procedures followed at Glasgow University. The research was restricted to the application of some psychological tests to the pupils and later the tracing of their attainment in the chemistry examinations both internal and external ("O" Grade).

4.10 A test applied

The psychological test applied to the sample was the digit backward test (DBT). It was found difficult to apply any other test in the schools due to timetable restrictions.

Table 23

The groups of holding/thinking space in the schools

Schools	X - 5	X - 6	X - 7	Total
Hucheson's	32	34	60	126
Graeme	25	10	29	64
Trinity	15	16	18	49
Stirling	20	12	11	43
Total	92	72	118	282

The researcher marked the answer sheets of the test and subdivided the sample into three groups according to the pupils' holding/thinking space. The result is displayed in table 23.

4.11 The Hucheson's examination

In January 1988, the pupils of Hucheson's Grammar School sat an internally set chemistry examination. The questions were analysed and 6 of them were used for the study. The Z-demand of questions was distributed from 2 to 9 and no question was found of 7 or 8 as shown in appendix 12. Therefore, no accurate result could be extracted from the performance of the pupils in the examination in this middle region.

Accordingly, the X=6 and the X=7 pupils were affected much more than the others and such pupils were unable to show a clear decline in performance when the Z-demand exceeded their capacity.

However, the sample has reduced to 105 since 21 pupils did not sit in the examination. The facility value for each question versus the pupils capacities is shown in table 24.

Table 24

The F.V. for each question of the chemistry examination versus the pupils capacities

Groups \ Questions	Q1 Z - 2	Q2 Z - 3	Q3 Z - 4	Q4 Z - 5	Q5 Z -6	Q6 Z - 9
X - 5 (N - 29)	0.86	0.78	0.67	0.67	0.37	0.17
X - 6 (N - 31)	0.86	0.73	0.70	0.70	0.63	0.10
X - 7 (N - 45)	0.95	0.75	0.84	0.69	0.60	0.20

Furthermore, the researcher used again the Kellet [47] method to find out the significant differences of the questions between the groups. The result has displayed in table 25.

Table 25

The significance of the F.V. differences for each question of the chemistry examination between the pupils' groups.

Questions \ Group differences	X-5 & X-6	X-6 & X-7	X-5 & X-7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	S***	N. S	N. S
Q5 Z = 6	N. S	N. S	S***
Q6 Z = 9	N. S	N. S	N. S

*** At 10% level

The curves which emerged from the performance of the Hucheson pupils in this examination are shown in figure 4.4.

The X=5 and the X=6 pupils declined rapidly after the Z-demand exceeded their capacity. It is not apparent how those pupils performed at Z=7 and Z=8. Nevertheless, some of them still survived at Z=9. The X=7 pupils began to decline earlier than expected and no exhibition of their performance at Z=7 or Z=8 could be examined as no question was found to have that demand.

Generally, the result shows a high attainment for all groups and the S-shape curve is more raised than in previous examples. The reason for that is due to the quality of pupils from Hucheson's Grammar School which is an independent school and admits only able pupils on a competitive basis. However, even with this group, the effect of capacity versus performance shows up.

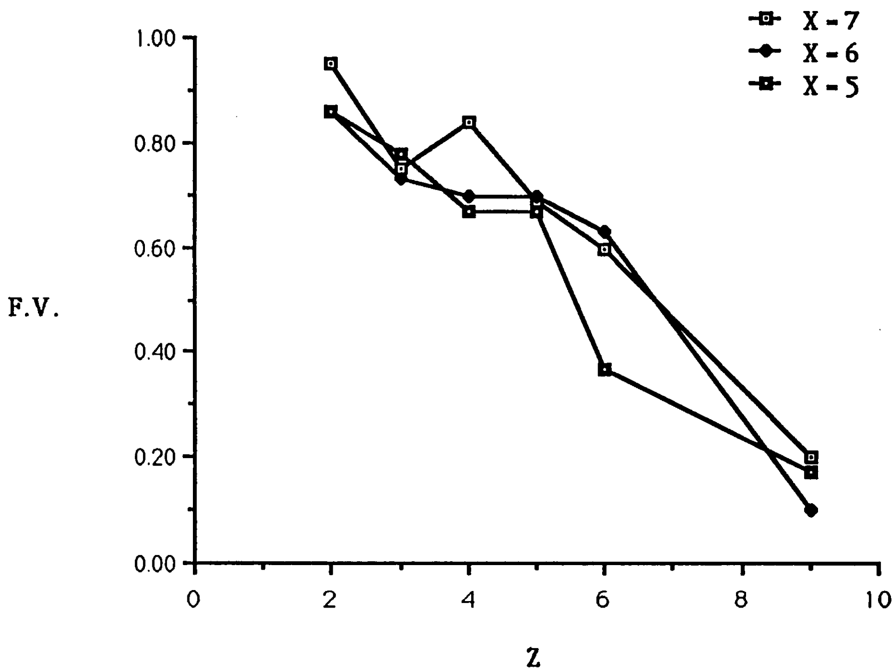


Figure 4.4 The performance of the Hucheson sample in the chemistry examination.

4.12 The Graeme examination

In December 1987 the pupils of Graeme High School sat an internally set chemistry examination. The researcher examined the question sheet and found 6 questions which had demands distributed from 2 to 7. The analysis of the questions into demands is to be found in appendix 13. Furthermore, one pupil of the X=5 did not sit this exam.

It is possible to suggest, from the demands of the questions, that the X=7 pupils would not be able to exhibit their performance as no question were found to have a demand which exceeds 7. The facility value of the questions was taken into account and the result is shown in table 26.

The significance of the facility value differences is to be found in table 27. The pattern which emerges from the three curves of the pupils' groups is shown in figure 4.5.

Table 26

The F.V. for each question of the chemistry examination versus the pupils capacities

Questions / Groups	Q1 Z = 2	Q2 Z = 3	Q3 Z = 4	Q4 Z = 5	Q5 Z = 6	Q6 Z = 7
X = 5 (N = 24)	0.96	0.60	0.48	0.58	0.31	0.21
X = 6 (N = 10)	0.90	0.80	0.60	0.63	0.55	0.30
X = 7 (N = 29)	0.97	0.62	0.61	0.64	0.48	0.45

Table 27

The significance of the F.V. differences for each question of the chemistry examination between the pupils' groups.

Questions / Group differences	X-5 & X-6	X-6 & X-7	X-5 & X-7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	N. S	N. S	N. S
Q5 Z = 6	N. S	N. S	N. S
Q6 Z = 7	N. S	N. S	S***

*** At 10% level

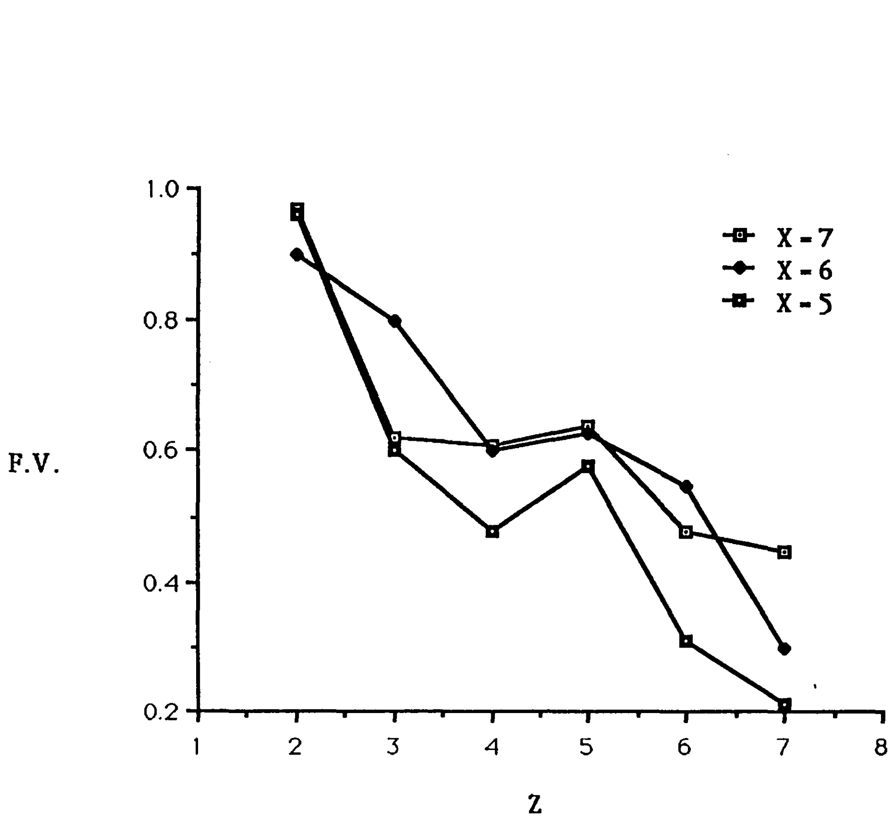


Figure 4.5 The performance of the Graeme sample in the chemistry examination.

As predicted, the pattern could not show the actual performance of the X=7 pupils since no question exceeds Z=7. However, the X=7 group declined gradually with the increasing complexity of the tasks.

The X=6 pupils showed a typical performance and declined rapidly at Z=7.

The X=5 pupils plunged rapidly after the Z-demand exceeded the pupils' capacity.

4.13 The Trinity examination

The research sample sat a chemistry examination earlier in 1988. 20 pupils did not attend this exam, 6 of the X=5 pupils, 8 of the X=6 pupils, and 6 of the X=7 pupils.

The question sheet was analysed and 7 questions were found to range from 2 to 8 demands. The number of thought steps is to be found in appendix 14. The facility value of each question is laid out in table 28.

The significance of the facility value differences is displayed in table 29.

The pattern which emerges from the performance of the sample in the chemistry examination is shown in figure 4.6.

Table 28

The F.V. for each question of the chemistry examination versus the pupils' capacities

Questions / Groups	Q1 Z=2	Q2 Z=3	Q3 Z=4	Q4 Z=5	Q5 Z=6	Q6 Z=7	Q7 Z=8
X = 5 (N = 9)	0.92	0.71	0.50	0.50	0.39	0.19	0.08
X = 6 (N = 8)	0.80	0.80	0.50	0.35	0.50	0.23	0.20
X = 7 (N = 12)	1.00	0.90	0.40	0.44	0.53	0.34	0.20

Table 29

The significance of the F.V. differences for each question of the chemistry examination between the pupils' groups.

Group differences / Questions	X=5 & X=6	X=6 & X=7	X=5 & X=7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	N. S	N. S	N. S
Q5 Z = 6	N. S	N. S	N. S
Q6 Z = 7	N. S	N. S	N. S
Q7 Z = 8	N. S	N. S	N. S

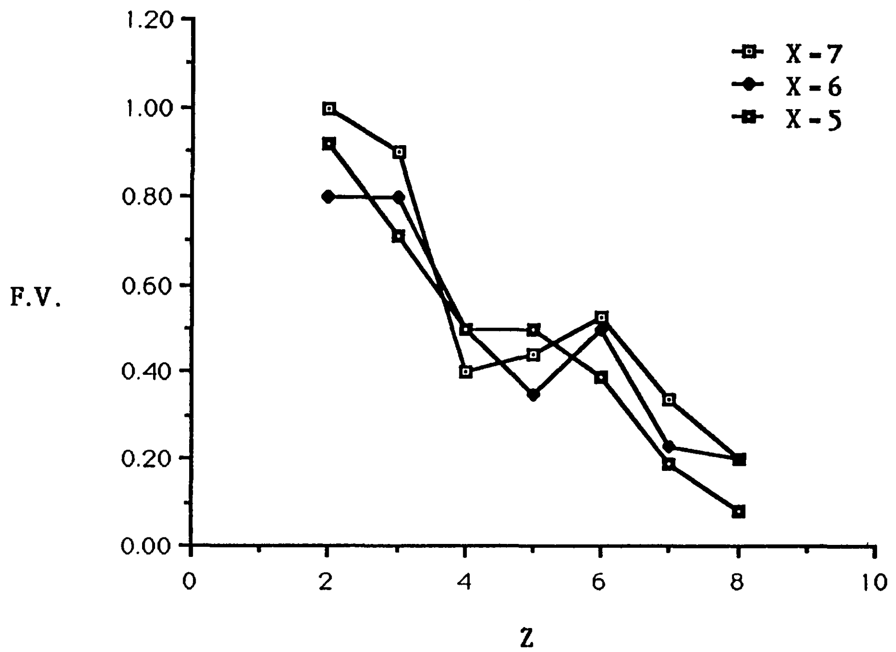


Figure 4.6 The performance of the Trinity sample in the examination.

The pattern reveals that almost all the pupils declined at the beginning of the task starting from Z=3, then they made a temporary recovery at Z=6 excepting the X=5 pupils who declined gradually till the Z=6 and then declined rapidly like the others.

4.14 The Stirling examination

As soon as the pupils finished their chemistry examination in January 1988 the question sheet was analysed and 8 questions were found to have demands distributed from 2 to 9. The demands of the questions are exhibited in appendix 15.

The research lost one pupil of the X=5 pupils who not attend this exam. The facility value for the questions is shown in table 30.

Moreover, the significance of the facility value has been assessed and the result is displayed in table 31.

Table 30

The F.V. for each question of the chemistry examination versus the pupils' capacities

Questions / Groups	Q1 Z = 2	Q2 Z = 3	Q3 Z = 4	Q4 Z = 5	Q5 Z = 6	Q6 Z = 7	Q7 Z = 8	Q8 Z = 9
X = 5 (N = 19)	0.68	0.79	0.71	0.63	0.33	0.26	0.31	0
X = 6 (N = 12)	0.92	0.83	0.63	0.63	0.46	0.17	0.25	0.08
X = 7 (N = 11)	0.82	0.73	0.73	0.78	0.53	0.55	0.27	0.10

Table 31

The significance of the F.V. differences for each question of the chemistry examination between the pupils' groups.

Group differences / Questions	X=5 & X=6	X=6 & X=7	X=5 & X=7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	N. S	N. S	N. S
Q5 Z = 6	N. S	N. S	N. S
Q6 Z = 7	N. S	S***	N. S
Q7 Z = 8	N. S	N. S	N. S
Q8 Z = 9	N. S	N. S	N. S

*** At 10% level

The three curves of the groups were plotted together and the pattern which emerged from that is shown in figure 4.7.

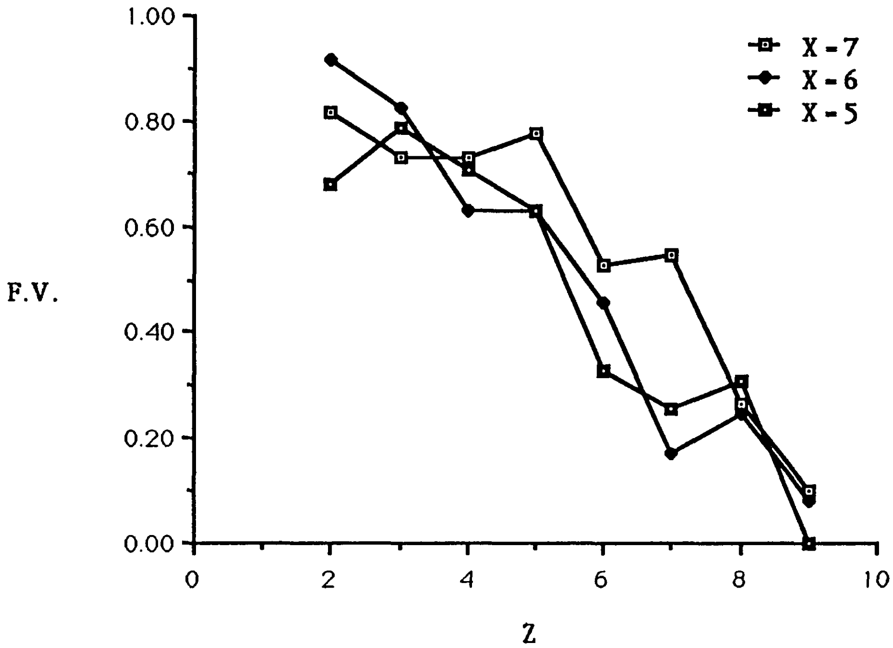


Figure 4.7 The performance of the sample in the chemistry examination.

The performance of the X=5 pupils and the X=6 pupils declined rapidly soon after the Z-demand exceeded their capacity and it is possible to see that the performance of the X=6 pupils declined more precipitately than others at Z=7, but both groups have made a temporary recovery at Z=8 and then declined again. The sudden recovery of the X=5 pupils seems to have been temporary since it did not continue and declined rapidly to zero after that.

4.15 A combination of the chemistry examination results of all the samples from the respective schools

Despite the fact that the results were gleaned separately from the schools, a combination of the results was found to be necessary since it indicates the general performance of the pupils in chemistry examinations.

Table 32

The mean score of the F.V. of each question for the attainment of all the samples in the schools

Questions / Groups	Q1 Z = 2	Q2 Z = 3	Q3 Z = 4	Q4 Z = 5	Q5 Z = 6	Q6 Z = 7	Q7 Z = 8	Q8 Z = 9
X = 5 (N = 81)	0.86	0.72	0.59	0.60	0.35	0.22	0.20	0.09
X = 6 (N = 61)	0.87	0.79	0.61	0.58	0.54	0.23	0.23	0.09
X = 7 (N = 97)	0.94	0.75	0.65	0.64	0.54	0.45	0.24	0.15

Table 33

The significance of the F.V. differences for the mean score of the chemistry examinations between the pupils' groups.

Group differences / Questions	X=5 & X=6	X=6 & X=7	X=5 & X=7
Q1 Z = 2	N. S	N. S	N. S
Q2 Z = 3	N. S	N. S	N. S
Q3 Z = 4	N. S	N. S	N. S
Q4 Z = 5	N. S	N. S	N. S
Q5 Z = 6	S*	N. S	S*
Q6 Z = 7	N. S	S**	S**
Q7 Z = 8	N. S	N. S	N. S
Q8 Z = 9	N. S	N. S	N. S

* At 5% level ** At 1% level

The facility value for each question (demand) in all the schools' examinations was taken into consideration in order to determine the average attainment of the pupils in questions of the same demand.

Table 32 shows the combined facility value for each demand and the significant of the frequency of the mean score is shown in table 33.

Furthermore, the pattern which is evident from the average attainment of the pupils is exhibited in figure 4.8. The curves are to be found separately in appendix 16.

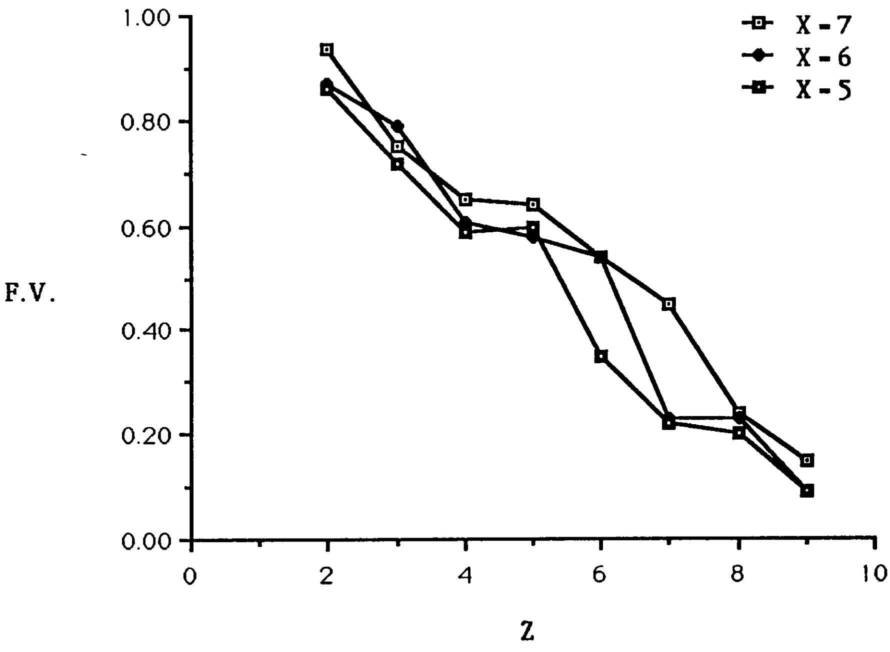


Figure 4.8 The average performance of all the samples in the chemistry examinations.

4.16 The general S-shaped curve results of the schools

Some points are apparent concerning the general results of the pupils in schools. The pupils, in general, have achieved well, obtaining remarkable results in the chemistry examinations, in addition there was a good correspondence to the model of this hypothesis which the research works upon.

The performance of the X=5 pupils declined rapidly after the Z-demand exceeded their capacity and such pupils rest in third place in the achievement.

The X=6 pupils lie in the second position, they dropped down rapidly at Z=7 and more rapidly at Z=9.

The X=7 pupils enjoy the first position since they achieved quite well and they declined gradually till Z=7, then declined rapidly like others. Some of the pupils from each group could still survive at Z=9.

CHAPTER FIVE

The effective of field-dependent/independent cognitive style on chemistry performance

5.1 The field-dependent and field-independent cognitive styles

Witkin confirms [49] that the field-dependent and the field-independent cognitive styles are related to the theory of differentiation. The differentiation theory, on the other hand, is related to the complexity of structure of the psychological system in which the organism has to function. One aspect of this theory is the segregation of the self from the outside world, in other words, self-nonself segregation would be one instance of how the differentiation shows itself in the organism.

Witkin assumes that users of field-dependence prefer to rely on external referents in processing information, while in contrast, users of field-independence prefer to rely on internal referents in processing information. Witkin states "the tendency to rely primarily on internal referents in a self-consistent way we designate a field-independent cognitive style. The tendency to give greater credit to external referents is a field-dependent cognitive style".

Witkin, Dyk, Goodenough, and Karp suggest [50] that the field-dependence/ independence dimension is related to the ability to overcome an embedding context which appears distinct from the ability to overcome the effect of distracting fields.

In brief, Witkin and his colleagues define an individual who can easily 'break up' an organised perceptual field and separate readily an item from its context, as a field-independent individual, whereas the individual who has insufficient ability to separate an item from its context and readily accepts the dominating field or context would be defined as a field-dependent individual [51].

5.2 Hypotheses in field-dependence/independence and in learning and memory

The empirical work which has been done on the learning and memory of field-dependent/independent people has produced three interpretations;

(i) the interpretation of Goodenough [52] and his colleagues who believe that "field-dependent and field-independent people differ more consistently in how the learning or memory process occurs than in how effective the process is".

(ii) the interpretation of Pascual-Leone and his colleagues who suggest that [53] field-independent people are more advanced developmentally than field-dependent people.

(iii) the interpretation of others who suggest that field-independent people are consistently better in task-solving than field-dependent people.

5.2.1 Some characteristics of field-dependent/independent people in the Goodenough hypothesis

Relying on the results of field-dependence/independence research which he had pursued with his colleagues, Goodenough [52] emphasises that field-dependent people have a relatively global cognitive style which governs their experiences by the organisation of the field. By contrast, field-independent people have a relatively analytical cognitive style which allows their experiences to be analysed and developed.

Goodenough indicates that field-dependent people are dominated by the most salient attribute of the stimulus and are incapable to restructuring the field as required by the task so that they tend to accept the organisation of the field as given. Whereas field-independent people have the ability to restructure the field as is required.

Furthermore, Goodenough points out [52] that many studies have suggested that the tendency of field-independent people is to adopt the participant role in the learning process which gives an indication of their greater structuring ability while the tendency of field-dependent people is to adopt the role of the spectator.

Goodenough concludes from the findings that there is not much difference between the two kinds of people when involved in general associative learning. The individual differences in field-dependence may only arise from complexity related to learning effectiveness. Goodenough states "field-independent people learn or remember significantly more than field-dependent people under some conditions (e.g., intrinsic motivation, discrimination learning when nonsalient cues are relevant), but field-dependent people are superior under other conditions (e.g., incidental learning of social stimuli, negative response-contingent reinforcement)".

Field-dependent people tend to depend on the external environment more than field-independent people for performing their tasks. In conclusion, field-dependent people are more attentive to cues from other people. Although they need to rely specifically on people in ambiguous situations they do not rely on them in unambiguous situations. In contrast, field-independent people seem to be more 'self-sufficient' than others.

5.2.2 Some characteristics of field-dependent/independent people in the Pascual-Leone hypothesis

Pascual-Leone refers [18] to the finding of Witkin in field-dependence/ independence and regards field-dependent people as those who function with an M size inferior to their structural capacity. Pascual-Leone demonstrates that field-independent people are high M-processors whereas field-dependent people are low M-processors. He concludes, as mentioned in the first chapter, that all cognitive processing takes place in a central computing space called 'M'.

Case supports [54] the hypothesis of Pascual-Leone in its method of interpreting the field-dependence/independence. By practical research he found that some subjects performed poorly in his test as they employed an insufficient central computing space M while others did well as they used an efficient central computing space M.

Pascual-Leone indicates that field-dependence decreases with the development of individuals (up to age 16) Case affirms [54] that "the measured decrease in field-dependence is exclusively a function of developmental changes in M-space and in the conceptual knowledge or processes coordinated in this M-space".

Additionally, Case supports the findings of Witkin that field-dependent people communicate with the external environment much more than field-independent people. Therefore, Case suggests that it is prudent to supply field-dependent people with assistance by firstly drawing on the average or above-average M-space which they often use, and secondly, by teaching them sophisticated strategies which would facilitate their learning while reducing their mistakes.

5.2.3 The approach of other research

The third group of researchers have demonstrated [53] that field-independent people perform more effectively than field-dependent people. It seems that this approach has come into existence by relying on the interpretation of Pascual-Leone [18] that field-dependent/independent people differ in the use of various cognitive processes.

Davis and Frank conclude [53] from their study that field-independent students perform more efficiently than field-dependent students and that both sets of students employ different encoding strategies, or when they employ the same strategy the effectiveness of it would vary.

Davis and Frank maintain that the poor performance of field-dependent students is due to their less efficient memory as well as having difficulty in remembering the task which has been set. In conclusion, Davis and Frank do not support the findings of Goodenough [52] that what differentiates between field-dependent and field-independent people is the process they employ. Instead, they support the suggestion that field-independent people are more efficient than field-dependent people.

As hypothesised by some researchers, field-independent people seem to recall information stored in the long-term memory more efficiently than field-dependent people especially when the load of information is high and when potential interference is imminent.

Accordingly, on 'higher-order tasks', Frank notes [55] that field-independent learners perform better and more accurately than field-dependent learners. On 'lower-order tasks', the same accuracy is still apparent in the performance of field-independent learners than the field-dependent learners, unless the 'external storage conditions' of the latter group help to compensate for their deliberate and passive processing style.

Frank, in another study, points out [56] that field-dependent/independent learners may differ in the effectiveness of their performance in certain conditions.

5.3 The present study of field-dependence and field-independence

According to Pascual-Leone [18] the field-dependent/independent cognitive style could restrict the learner from employing his full mental space in solving tasks. Consequently, field-dependent learners may operate in a way which is below their actual X-space.

El-Banna assumes [57] that field-dependent students are not capable of discriminating between relevant and irrelevant information (signal from noise) as their limited holding/thinking space is being divided between the signal and the noise. Since they discriminate badly, scarce working space is being taken up with irrelevant 'noise'. As a result of that, the field-dependent student would lose his ability for solving tasks, especially in a complex situation.

The present study seems to support El-Banna's suggestion as some students, while being considered high capacity students, have obtained low marks in chemistry examinations. To determine the effectiveness of field-dependent/independent cognitive style on the performance of the students in chemistry problems , the researcher applied a 'Hidden Figures Test' (HFT) on his sample which contains both university students and school pupils. The HFT was designed by El-Banna [57], based upon Witkin's work.

5.4 Hidden Figures Test (HFT)

The general purpose of the Hidden Figures Test (HFT) is to classify the sample of the research into field-dependent learners who would find difficulty or be unable to discriminate a required item from its context, and field-independent learners who are able to discriminate the required item from its context. In other words, those who can separate the 'signal' from surrounding distracting 'noise'.

The HFT consists of 18 complex figures, in addition to 2 more which were inserted as examples. The designer of the test offers 6 simple geometric and non-geometric shapes which are embedded in the complex figures (one simple shape in each complex figure) and the subject must isolate these shapes. A sample of this test is to be found in appendix 17(a).

The test is exemplified on the first two pages of the test booklet using two examples. The third page of the test booklet consists of 6 simple shapes (geometric/non-geometric shapes) as a specimen of the type of shape to be found.

The subject is required to locate a hidden simple shape in each complex figure. He must then outline and trace it in pencil or pen against the lines of the complex figure. The subject has to follow certain conditions in the test;

(i) 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).

(ii) the subject is not allowed to use a ruler or any other means to measure the size of the simple shape in the complex figures.

(iii) there is more than one simple shape embedded in some complex figures but the subject is required to locate only the simple shape which is in the same proportion, size, and orientation as the specimen. If the subject finds more than one correct answer (one complex figure has more than one correct answer), then he is required to trace only one.

(iv) the test booklet should be collected from the subjects after 20 minute.

The HFT scoring key is located in appendix 17(b). The results of the test are calculated by allocating one mark per correct complex figure, after which the over-all test mark is calculated to ascertain the total mark which each subject gained. The maximum mark that can be obtained is 18 since the test comprises of 18 complex figures.

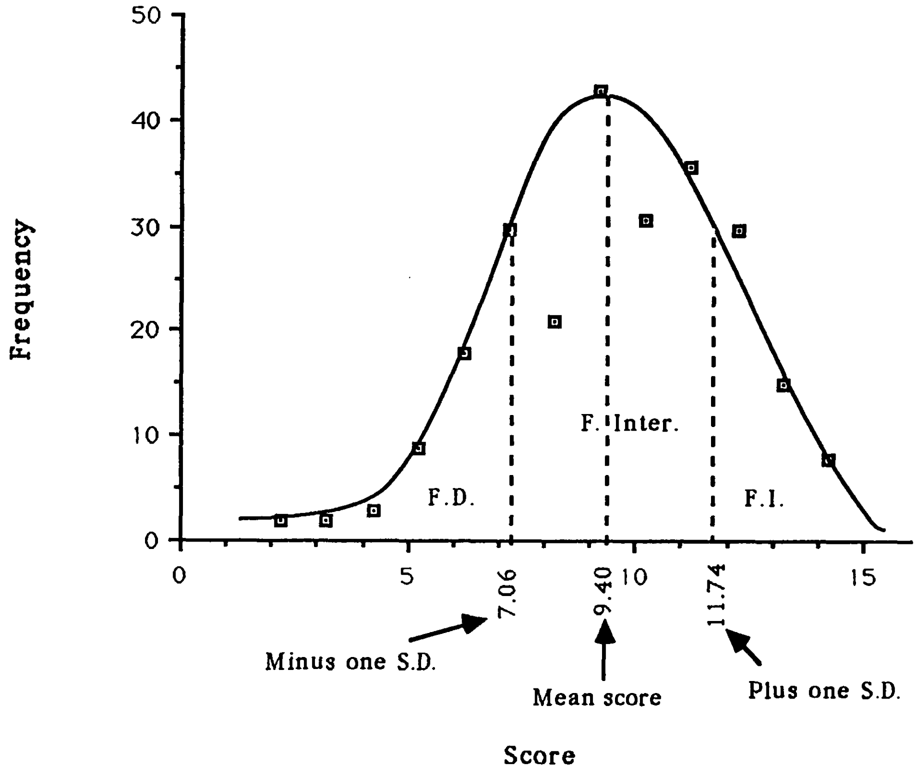
5.5 The procedure employed in the University of Glasgow

The procedure which is employed includes the following

5.5.1 Student sample

The researcher selected the first year of the chemistry students at Glasgow University from 1987-1988 as a sample for his study. The students' X-space was measured, as was detailed in the previous chapter, and their progress in the chemistry examinations was traced during the year.

The students who attempted the HFT were 235. The distribution of the HFT total scores for the sample is shown in figure 5.1.



S. D. Standard Deviation

Figure 5.1 The distribution of the HFT total scores for a sample of the university.

Table 34

Classification of the university sample

Group	Number of pupils
F-D	58
F-Int.	127
F-I	50
Total	235

The distribution of the HFT total scores divided the sample into three categories according to the attainment of students in the FD/FI measurement.

The criterion used in the division of the sample relies on the method which was employed by Case [17], Scardamalia [43], and Case and Globerson [54]. The criterion classifies the students who scored at least one standard deviation above the mean score as a field-independent student. On the other hand, the student who scored one standard deviation below the mean score is a field-dependent student. Moreover, the student who scored in between (±1) is classified as a field-intermediate student. Table 34 shows the classification of the university sample.

The researcher then sub-divided the sample according to the students' capacity which was obtained previously. Table 35 displays the classification of the FD/FI students versus their X-space.

Table 35

The classification of FD/FD students versus their holding/thinking space (N - 235)

Group	F-D	%	F-Int.	%	F-I	%	Total
X - 5	27	33.8	42	52.5	11	13.8	80
X - 6	14	21.9	37	57.8	13	20.3	64
X - 7	17	18.7	48	52.7	26	28.6	91

The percentages of the students exhibit that the majority of the X=5 students distributed as field-dependent and field-intermediate students whereas the majority of the X=7 students distributed as field-independent and field-intermediate students. The x=6 students, on the other hand, mainly distributed as field-intermediate students.

5.5.2 January examination

The students scores in the January chemistry examination were collected in order to compare the sample's attainment in the examination with their degree of FD/FI. The total mean scores of the students revealed that the field-independent students obtained the highest results, the field-intermediate students proved to be average and the field-dependent students obtained the lowest results. The students' mean scores and the standard deviations are shown in table 36.

Table 36
The students' mean scores and the standard deviations in the January examination

Group	Mean	S. D.
F-D (N=58)	55.5	17.5
F-Int.(N=127)	60.5	18.5
F-I (N=50)	62.9	20.6

The results tend to agree with the hypothesis that the mean score of field-independent students should be higher than the others and vice versa for the mean score of field-dependent students . But such an agreement may not be significant.

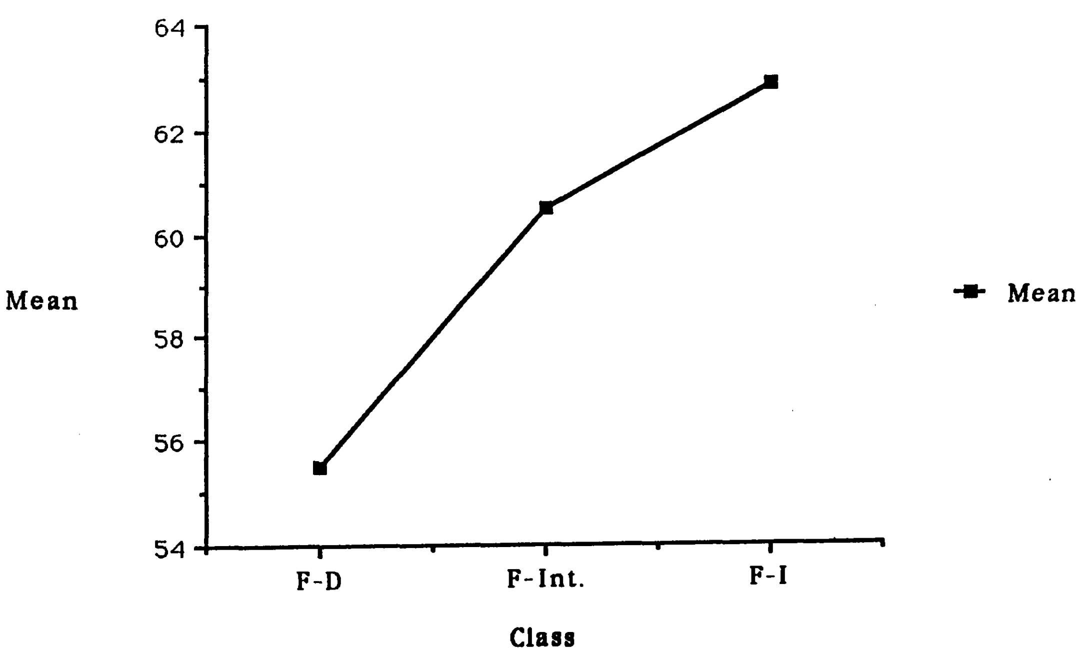


Figure 5.2 The students' mean scores regardless of X- capacity (January exam).

However, the mean scores of field-independent students is higher than the mean scores of field-intermediate students and these in turn are higher than the mean scores of field-dependent students. The mean scores of the sample in the January examination were plotted versus the students' groups of FD/FI and shown in figure 5.2.

Following the hypothesis of Pascual-Leone [18] the researcher could anticipate that field-independent students would perform better than the others in the January examination amongst all the groups with differing X-spaces.

Accordingly, the result found in table 35 was used to calculate of the mean scores and the standard deviations. Table 37 shows the result of the students related to differing X-spaces.

Table 37

The means and standard deviations for the students of different X-space in the January examination

Groups	F-D		F-Int.		F-I	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
X - 5 (N-80)	53.2	13.8	58.3	16.0	59.3	24.1
X - 6 (N-64)	56.5	18.9	58.5	19.6	63.8	19.4
X - 7 (N-91)	57.0	19.8	64.7	19.9	65.8	18.4

The mean scores obtained from the January examination are plotted and compared in figure 5.3. The figure indicates that the FD/FI cognitive style has influenced the X=5 students' attainments in the examination more than the X=7 students' attainments.

Nevertheless, it seems prudent to check these findings and therefore a scatter diagram is been drawn for each group of the students' capacities in addition to calculating the Pearson Product-Moment Correlation Coefficient [48] between the scores of students in the FD/FI and the chemistry examination as exhibited in figures 5.4, 5.5, and 5.6.

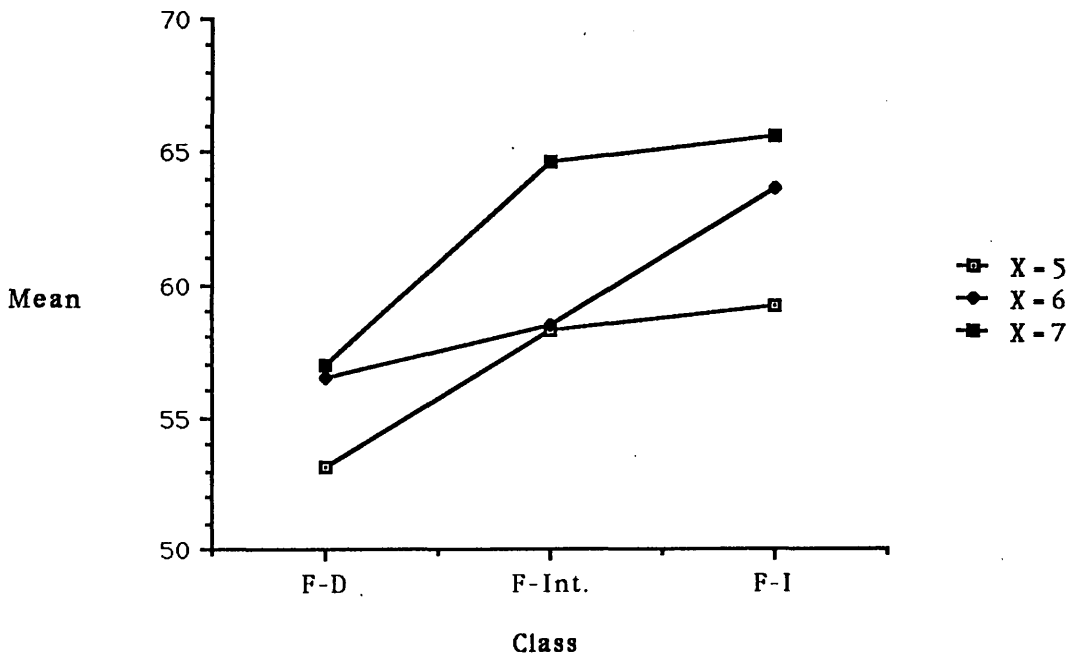
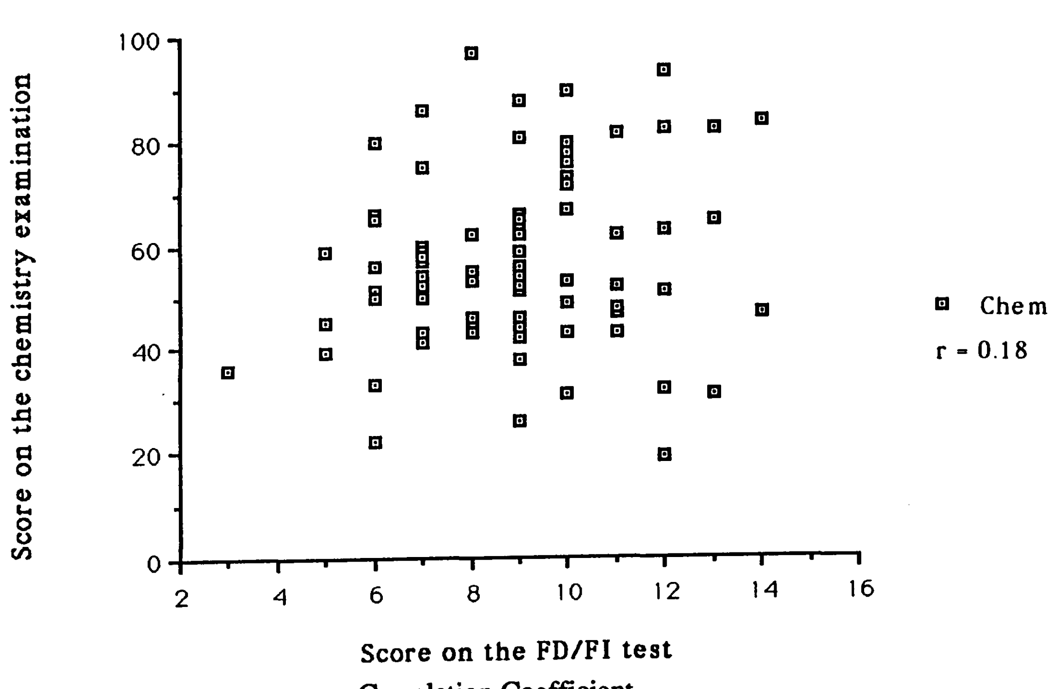
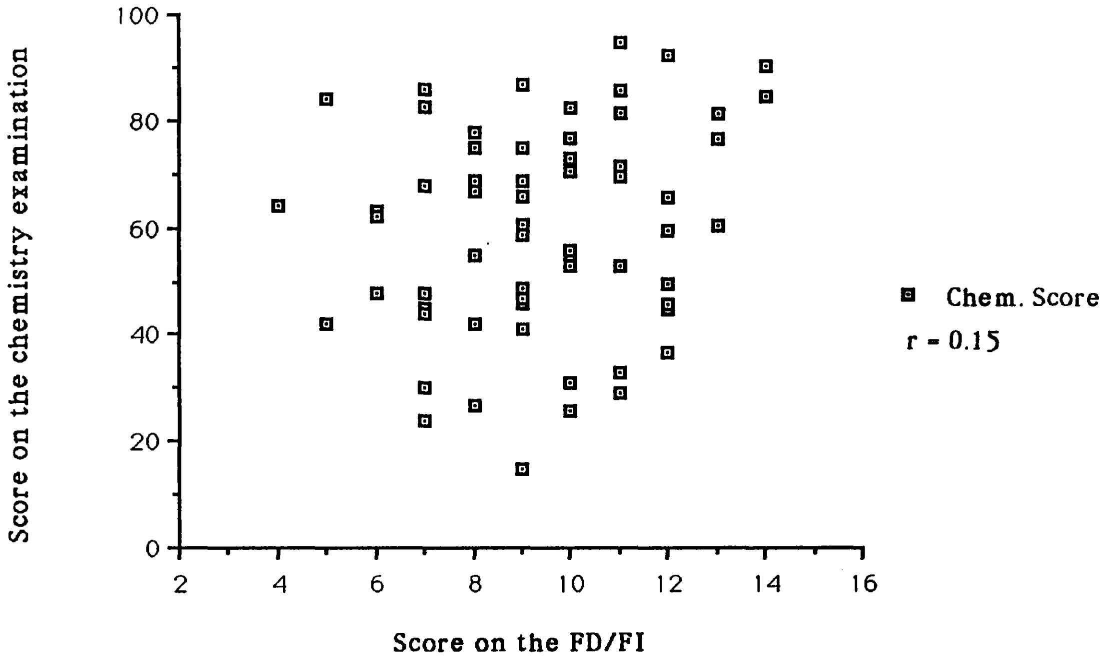


Figure 5.3 The mean scores for the students of different X-space and different degree of FD/FI in the January examination.



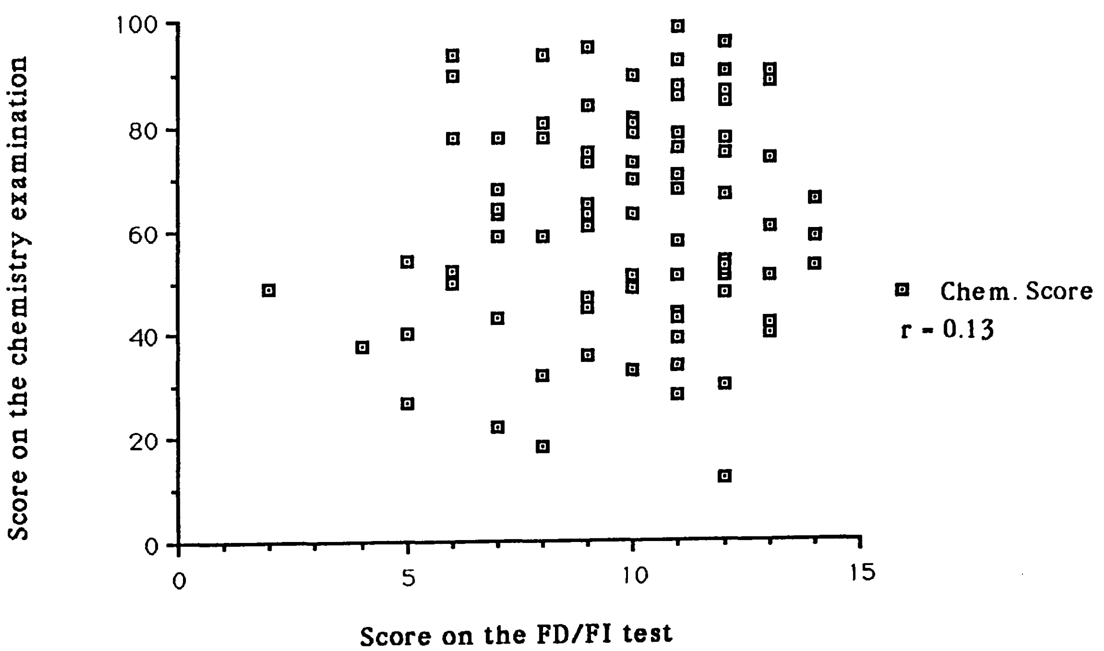
r = Correlation Coefficient

Figure 5.4 The scatter diagram for the X=5 students (January examination).



r = Correlation Coefficient

Figure 5.5 The scatter diagram for the X=6 students (January examination).



r = Correlation Coefficient

Figure 5.6 The scatter diagram for the X=7 students (January examination).

The scatter diagram of the X=5 students seems to be slightly more elongated than the scatter diagram of the X=6 students, but such elongation seems to disappear in the scatter diagram of the X=7 students.

Although the result obtained from the values of the Pearson Product-Moment Correlation Coefficient in the January chemistry examination is not particularly significant, an indication of support for the hypothesis is provided that the FD/FI cognitive style affects the performance of the X=5 students more than the others.

5.5.3 April examination

With the exception of five students, all the researcher's sample of the first year university students sat the April chemistry examination. The means of calculation used in the January examination were repeated. The students' mean scores and the standard deviations are displayed in table 38.

Table 38
The students' mean scores and the standard deviations in the April examination

Group	Mean	S. D.
F-D (N=57)	41.5	15.7
F-Int.(N=123)	43.3	16.4
F-I (N=49)	47.2	18.7

The above table agrees with the hypothesis that field-independent students would obtain the highest mean score , but again, not very decisively. Figure 5.7 shows the students' mean scores in the April examination versus their classes of FD/FI.

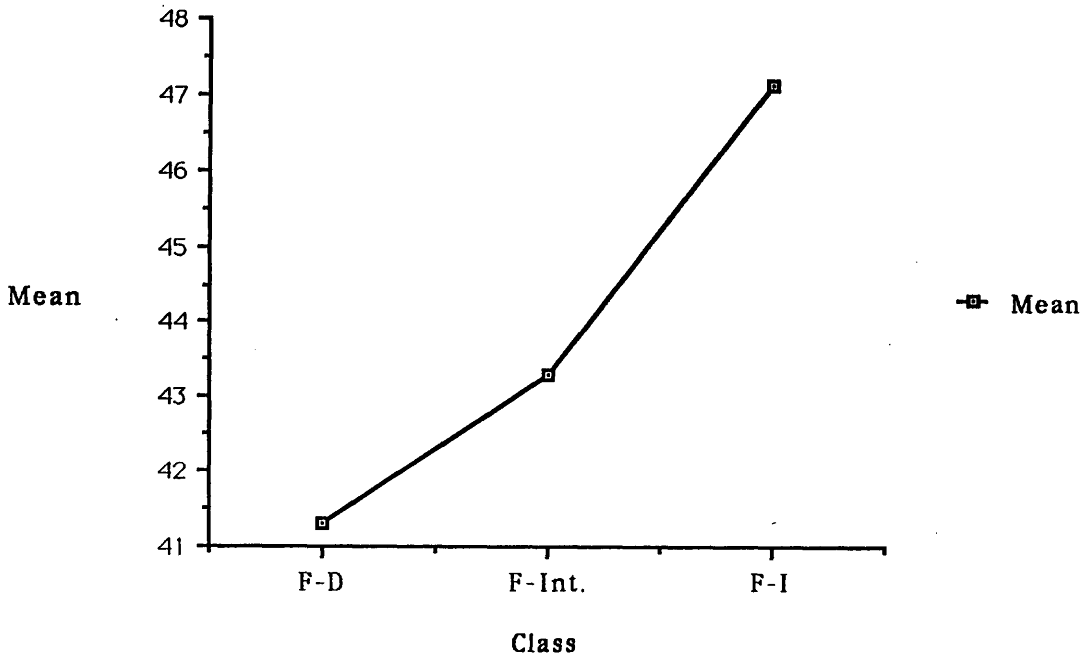


Figure 5.7 The students' mean scores in the April examination.

Then the researcher compared the April examination with the students' groups of the X-space and their classes of FD/FI cognitive style. The result which emerged is shown in table 39.

Table 39
The means and standard deviations for the students of different X-space in the April examination

Groups	F-D		F-Int.		F-I	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
X - 5 (N=77)	36.3	10.0	38.2	17.9	45.2	19.1
X - 6 (N=62)	42.1	16.1	44.8	12.3	47.4	17.1
X - 7 (N=90)	45.6	21.0	47.0	19.0	49.1	19.9

The mean scores from the above table are incorporated in figure 5.8.

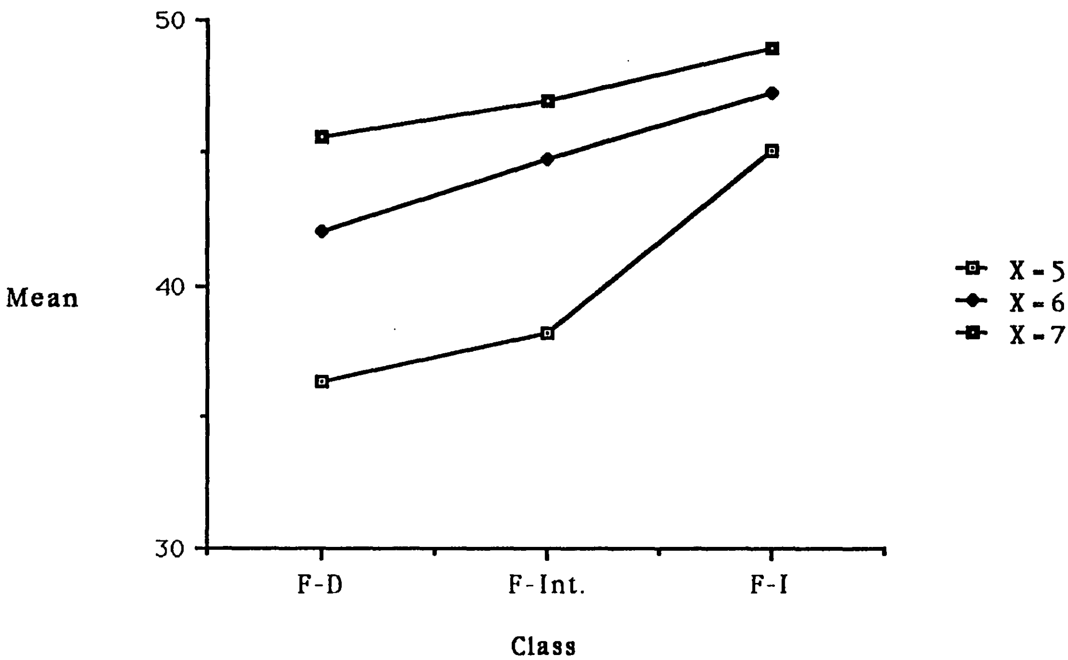


Figure 5.8 The mean scores for the students of different X-space and different degree of FD/FI in the April examination.

It seems that X=5 students are affected by the factor of FD/FI much more than X=7 students as occurred in the January examination, and the scatter diagram in addition to the Pearson Product-Moment Correlation Coefficient demonstrate that, as exhibited in figures 5.9, 5.10, and 5.11.

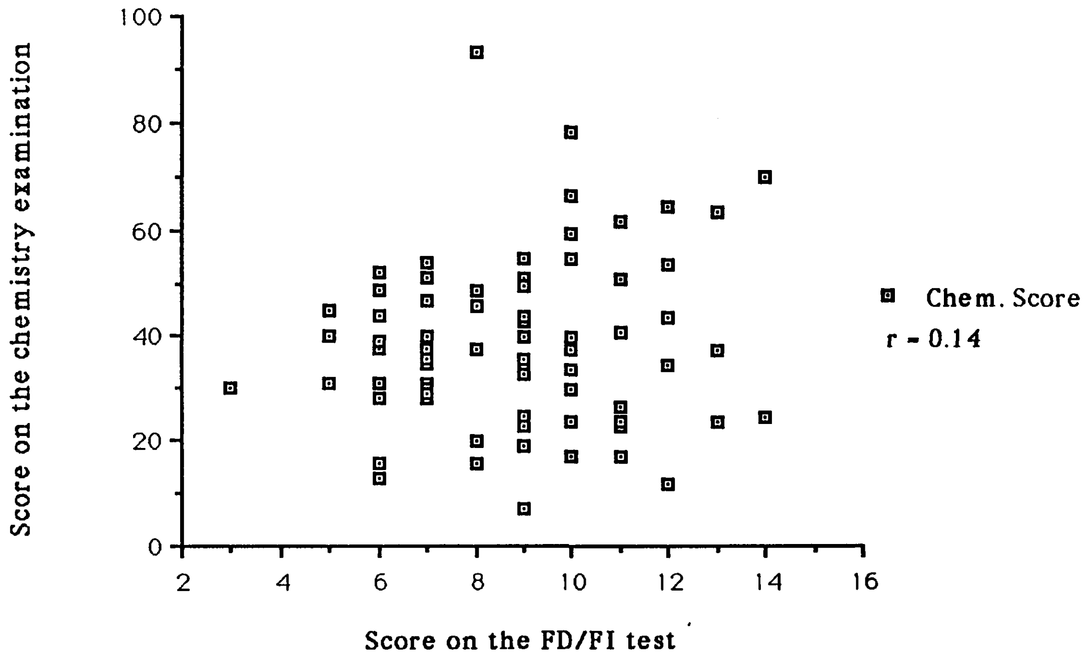


Figure 5.9 The scatter diagram for the X=5 students (April examination).

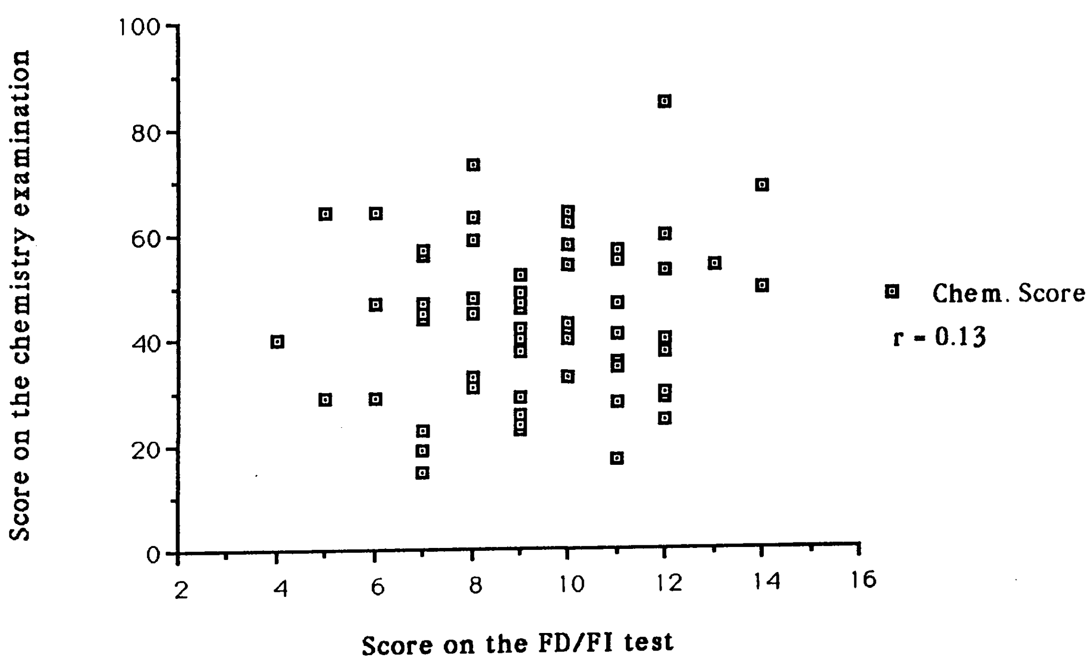


Figure 5.10 The scatter diagram for the X=6 students (April examination).

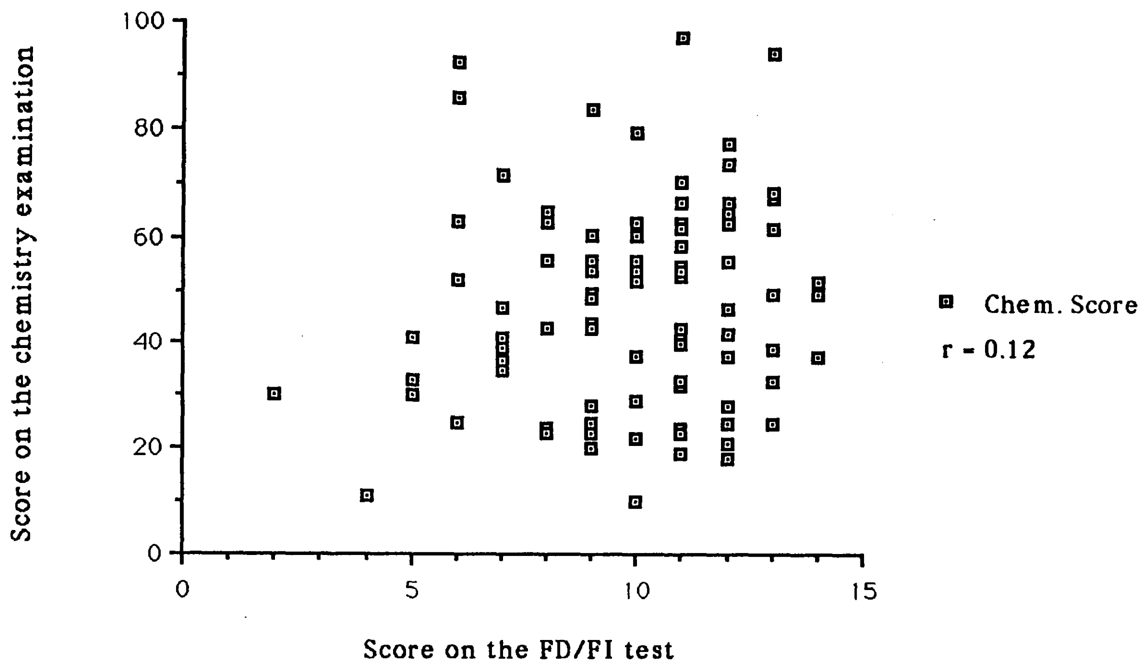


Figure 5.11 The scatter diagram for the X=7 students (April examination).

It is apparent from the above scatter diagrams that the slight elongations decrease with the increasing X-space of the students and almost disappear in the scatter plot of the X=7 students.

5.6 School sample

The school sample employed for the research comprises of the same pupils who participated the researcher's sample in the previous chapter. The number of the pupils who sat the HFT was 283.

The distribution of the HFT total scores for the sample is displayed in figure 5.12.

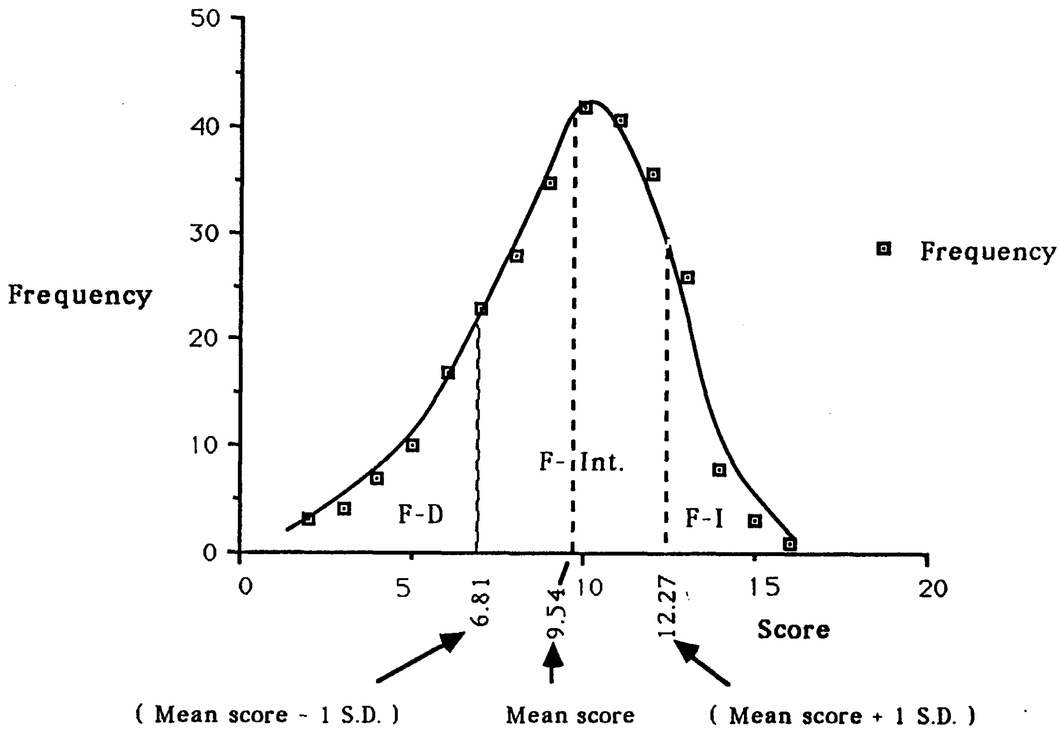


Figure 5.12 The distribution of the HFT total scores for the sample comprises of four schools.

The pupils are divided into three groups according to their attainments in the HFT and following the same criteria which were employed for university students. Table 40 shows the classification of the school sample.

Table 40
Classification of the school sample

Group	Number of pupils
F-D	40
F-Int.	205
F-I	38
Total	283

As the researcher had obtained the pupils' X-space values, he distributed them according to their holding/thinking space versus the degree of FD/FI. Table 41 shows this.

Table 41

The classification of FD/FD pupils versus their holding/thinking space (N - 283)

Group	F-D	%	F-Int.	%	F-I	%	Total
X = 5	27	28	64	70	0	0	91
X = 6	1	1.4	55	77	15	21	71
X = 7	12	10	86	71	23	19	121

The classification of the pupils in the above table shows a very significant correlation at better than 1% level as the Chi-square is equal to 43.69. Moreover, the percentages of the pupils exhibit that most of the X=5 pupils distributed as field-dependent and field-intermediate pupils whereas most of the X=7 students distributed as field-independent and field-intermediate pupils. The x=6 pupils, on the other hand, mainly distributed as field-intermediate pupils.

The next stage was to collect the pupils' attainments in the chemistry examination and make a comparison between them and the pupils' classification of FD/FI. Table 42 shows this comparison.

Table 42

The pupils' mean scores and the standard deviations in the chemistry examination (N - 260)

Group	Mean	S. D.
F-D (N=37)	57.0	16.1
F-Int.(N=188)	62.4	18.6
F-I (N=35)	75.9	13.5

It should be noted that 23 pupils from the sample did not attend the chemistry examination for various reasons. The mean scores in table 42 show a close correlation with the hypothesis since the field-independent pupils achieved better than the rest of the pupils. The field-intermediate pupils achieved more than the field-dependent pupils but less than the field-independent pupils.

The mean scores obtained from the chemistry examination were studied to determine any significant differences between them. Table 43 shows the significance of differences between the mean scores.

Table 43

The significance of the differences in mean scores of the pupils in the chemistry examination

Group	F-D	F-Int.
F-Int.	N. S	----
F-I	S**	S***

** Significant at 1% level

*** Significant at 10% level

The result indicates significant differences between the mean scores of field-independent pupils and both field-intermediate and field-dependent pupils. Thus these findings significantly support the hypothesis.

The mean scores were contrasted with the pupils' classes of FD/FI and are set out in figure 5.13.

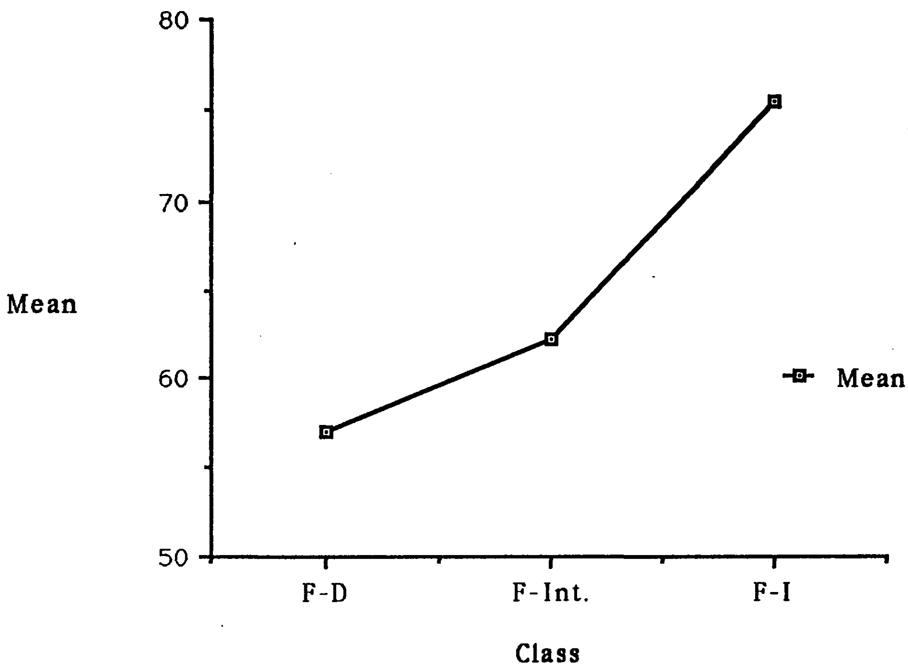


Figure 5.13 The pupils' mean scores in the chemistry examination.

The mean scores of the field-independent pupils were expected to be the highest of all the groups with different X-space as shown in table 44.

Table 44
The means and standard deviations for the pupils of different X-space in the chemistry examination

Groups	F-D		F-Int.		F-I	
	Mean	S. D.	Mean	S. D.	Mean	S. D.
X = 5 (N=86)	54.2	13.3	58.2	18.9	--	--
X = 6 (N=63)	60.0	0.0	63.4	20.4	74.7	11.4
X = 7 (N=112)	56.9	19.0	65.7	16.5	77.2	15.7

The mean scores of all the pupils are plotted and emerge in figure 5.14.

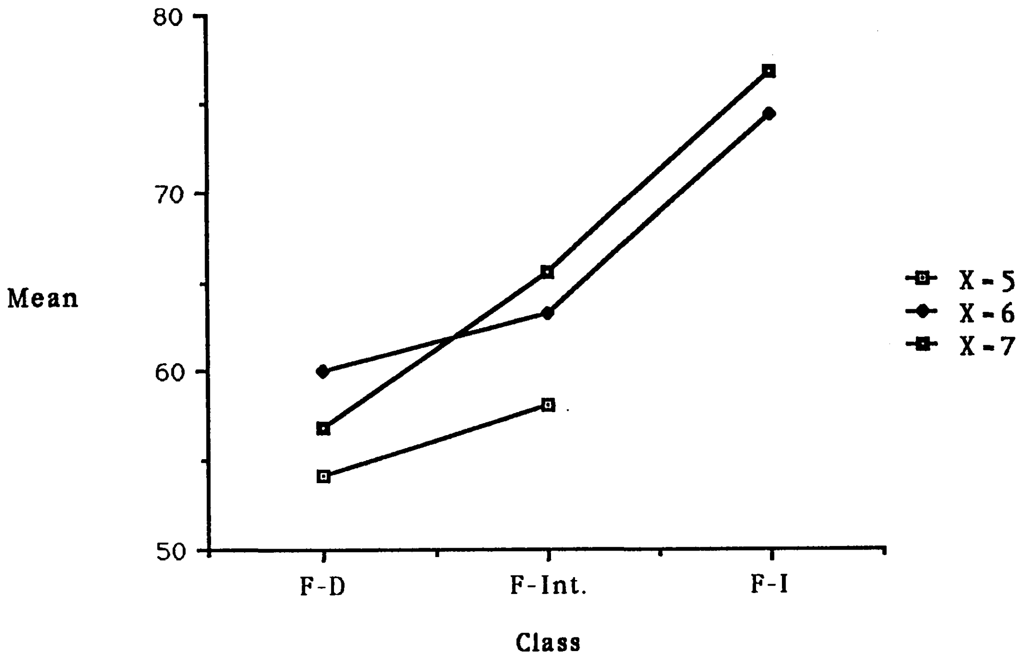
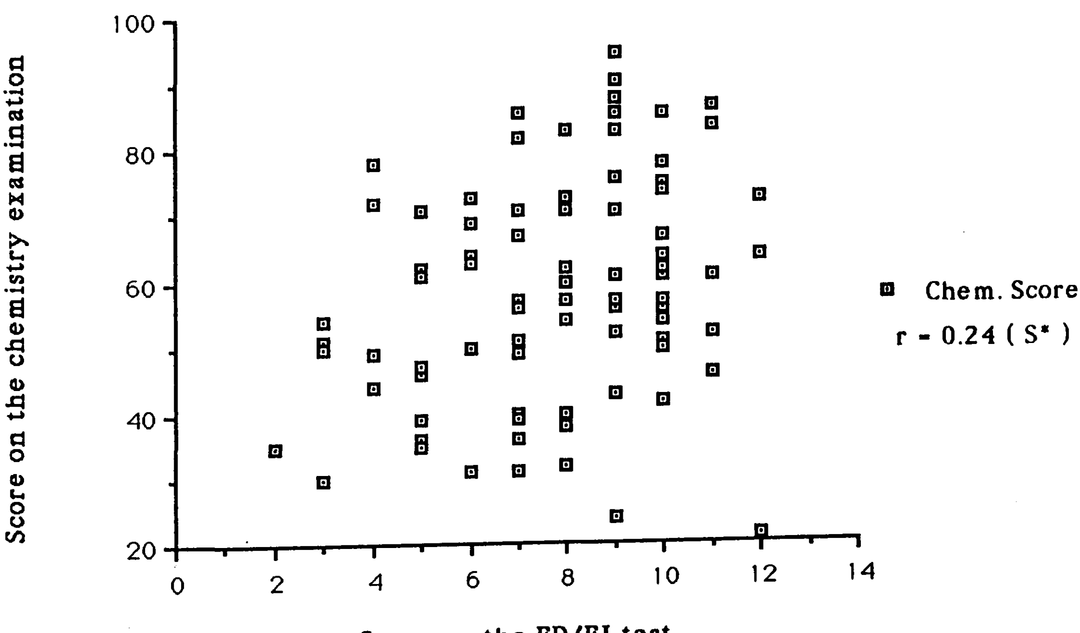


Figure 5.14 The mean scores for the pupils of different X-space and different degree of FD/FI in the examination.



* Significant at 5% level

Figure 5.15 The scatter diagram for the X=5 pupils in the chemistry examination.

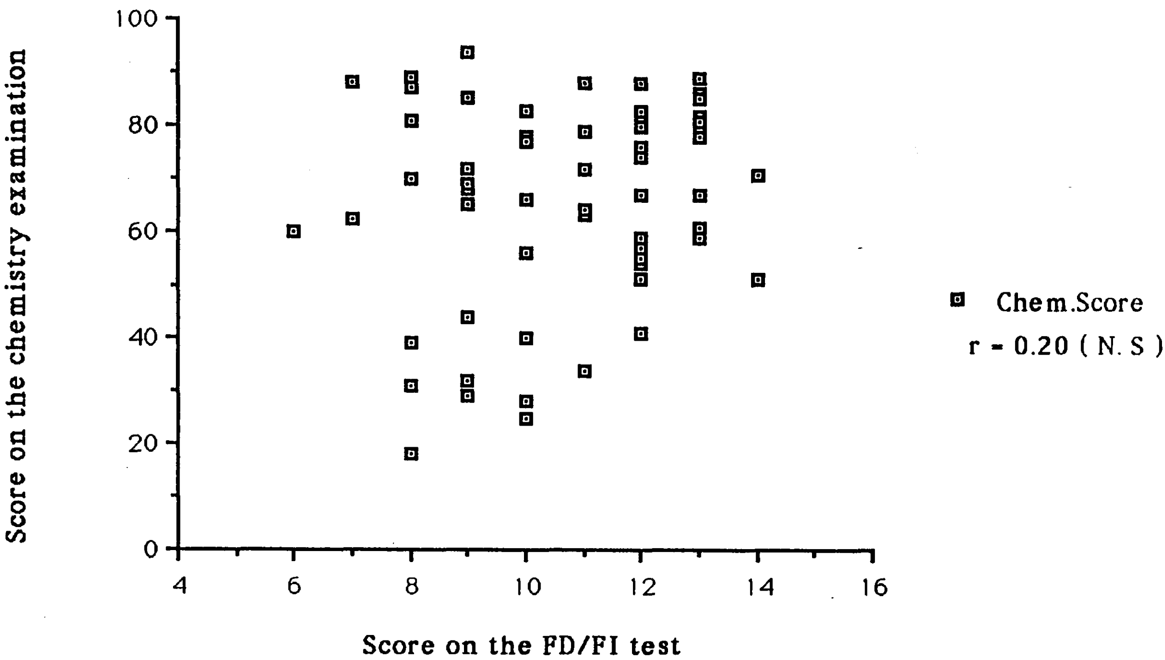
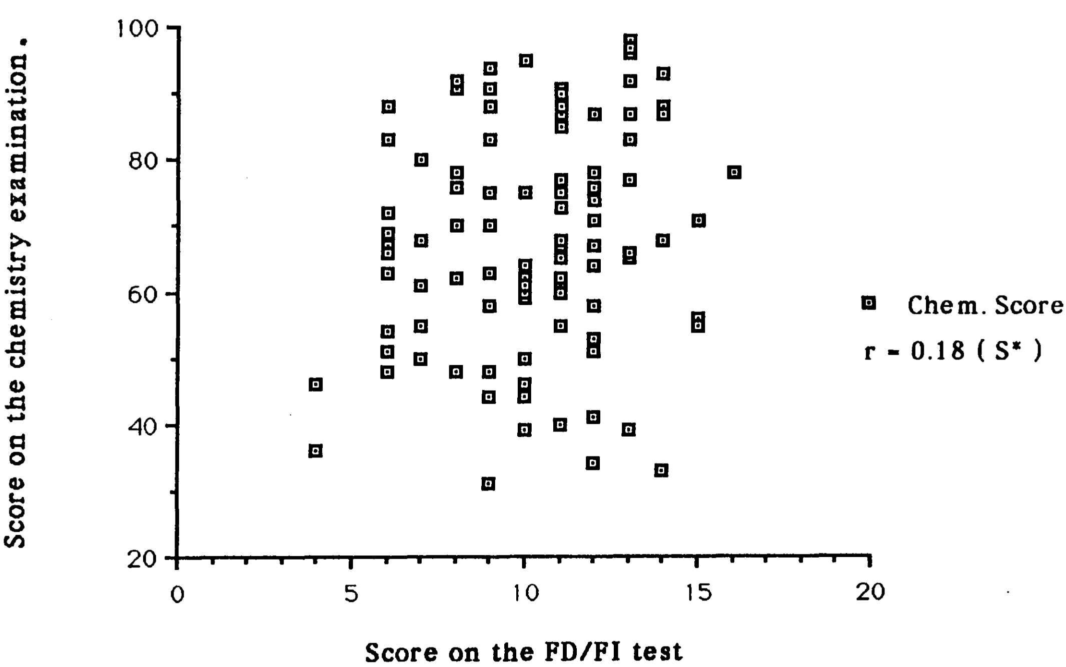


Figure 5.16 The scatter diagram for the X=6 pupils in the chemistry examination.



* Significant at 5% level

Figure 5.17 The scatter diagram for the X=7 pupils in the chemistry examination.

The finding has been checked by the scatter diagrams and by the Pearson Product-Moment Correlation Coefficient as seen in figures 5.15, 5.16, and 5.17.

The scatter plot of the X=5 pupils seems to be more elongated than the others which reflects the effect of the FD/FI cognitive style on those pupils who have less X-capacity. Additionally, the Correlation Coefficient is of significant value for the group of X=5 and for the group of X=7 at the 5% level.

5.7 The general trend of the results gathered from the university and the schools

The results of the samples obtained from the January and April university chemistry examinations and the schools' chemistry examination provided evidence that the FD/FI cognitive style could influence the attainment of the subjects in the chemistry examinations.

In each X-space group, it seems that field-independent subjects have the ability to obtain higher scores in the same examinations than the field-dependents. Additionally, the classification of the subjects into three groups according to their degree of FD/FI shows that the mean scores of the X=7 subjects in such examinations are higher than the X=6 subjects, while both are higher than the X=5 subjects.

Furthermore, the hypothesis might suggest that the X-space of the X=7 subjects is large enough to process and handle irrelevant material in the data given or required to solve the tasks. In other words, they can readily select the 'signal' and ignore the 'noise', their X-space have enough room for holding/thinking materials and even though the 'noise' could capture some of their X-space but they still have sufficient space for solving problems. Subsequently, it might be that the X=7 subjects' degrees of the FD/FI test do not affect their attainments in the chemistry examination (elongations disappeared). Whereas the situation for the X=5 subjects is completely different since the subjects have not enough space to handle irrelevant material and thus the HFT scores might be affected their attainments in the chemistry examination.

CHAPTER SIX

Information processing and 'Intelligence'

In response to a question which was raised during the research that is the X-space not just another name for an 'intelligence'. The researcher conducted a survey on the effectiveness of the measured intelligence to compare with measured X-space.

6.1 The procedure employed

6.1.1 The sample selected

Most schools do not subject their pupils to I. Q. or other intelligence tests. One school in our sample was found to do so. The sample which was selected for the study comprised 110 pupils from Hutcheson's Grammar School's. The researcher obtained the pupils' scores in an intelligence test called, 'Verbal Reasoning Test' which gave a Verbal Reasoning Quotient (V. R. Q.). The sample was restricted to the pupils of the above school as they had sat an intelligence test at Hucheson's Primary School.

It is worth mentioning that the Verbal Reasoning Test was applied on children in the age of 11 and the scores would not have changed much than the average in the age of 16 when this research has started its work on the same children.

6.1.2 The data gathered

The data which was gathered from the sample comprised of;

(i) the pupils X-space; obtained from the DBT.

(ii) the pupils degree of FD/FI; obtained from the HFT.

(iii) the pupils scores in the chemistry examination; obtained from the school (3 pupils did not sit the examination).

(iv) the pupils degree of intelligence; obtained from the school. The intelligence test (V. R. Q.) contains a set of puzzles which have to be solved by the subjects.

6.2 'Intelligence' compared with the X-space measurements, FD/FI measurements, and the chemistry examination results

It has been demonstrated in the previous chapters that the X-space of the subjects is an important factor in the chemistry performance. As the 'intelligence' factor may also be relevant to the present study and so the researcher believed it sensible to relate this factor with the X-space of the pupils and their scores in the chemistry examination.

6.2.1 'Intelligence' related to X-space

Working with the value (0.06) as obtained from the Pearson Product-Moment Correlation Coefficient when the pupils' V. R. Q. score were plotted against the X-space of each pupil, there is no significant correlation found between the intelligence and the X- capacity of the pupils.

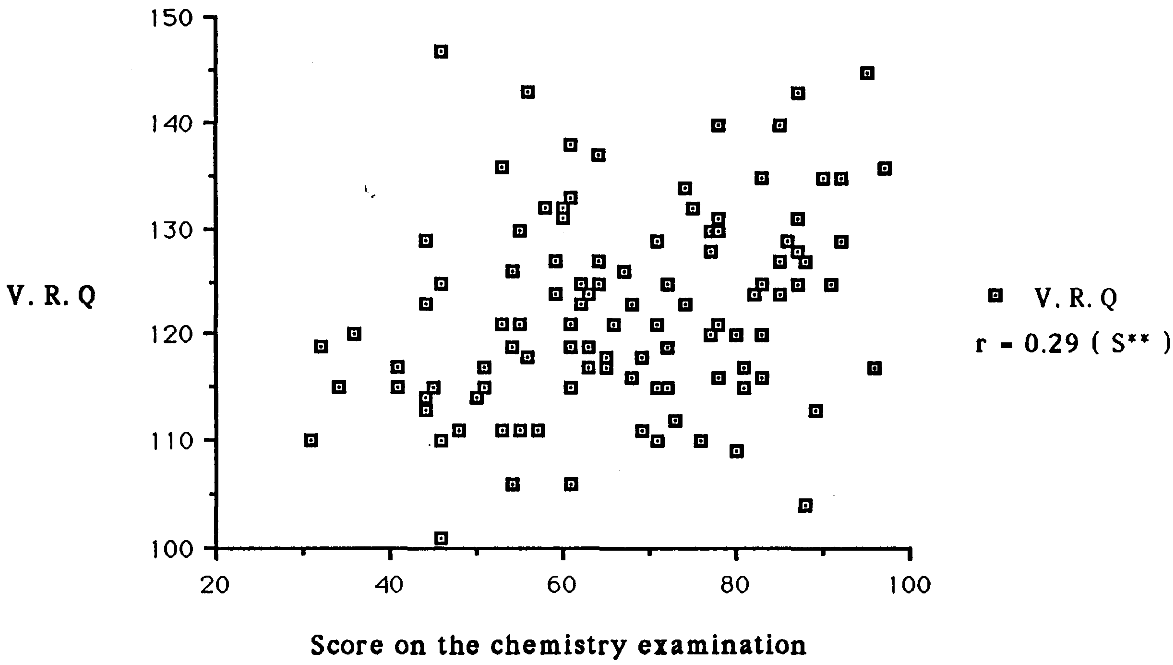
Such findings could be explained in that the intelligence test tasks may not exceed the X-capacity of any of the students and so the test is measuring something else. Also V. R. Q. was measured at primary school before X-space had fully developed.

6.2.2 'Intelligence' related to the chemistry examination results

The pupils' V. R. Q. scores were plotted versus the pupils' attainments in the chemistry examination. The emergent pattern is shown in figure 6.1.

The pattern exhibits a significant correlation between the two variables as the Pearson Product-Moment Correlation Coefficient is 0.29 (significant at the 1% level).

Therefore, one can see the effect of the 'intelligence' factor on the subdivided groups of the pupils according to their X-space. Figures 6.2, 6.3, and 6.4 displays this.



** Significant at 1% level

Figure 6.1 V. R. Q. score versus chemistry score.

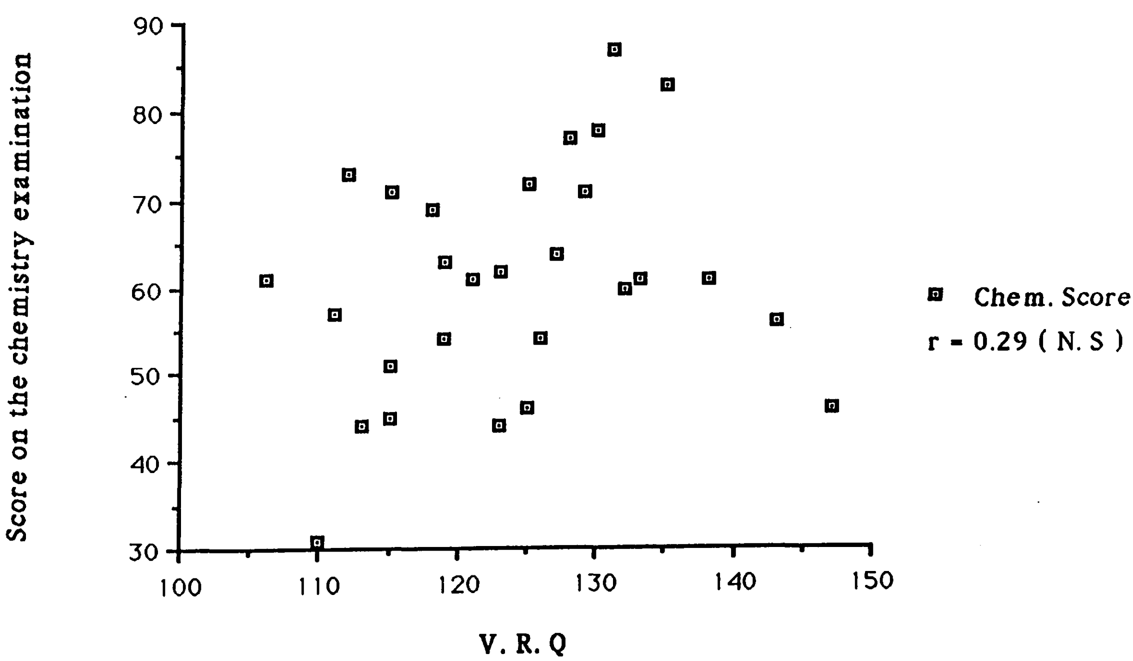


Figure 6.2 The X=5 pupils' attainments in the chemistry examination versus their V. R. Q. score.

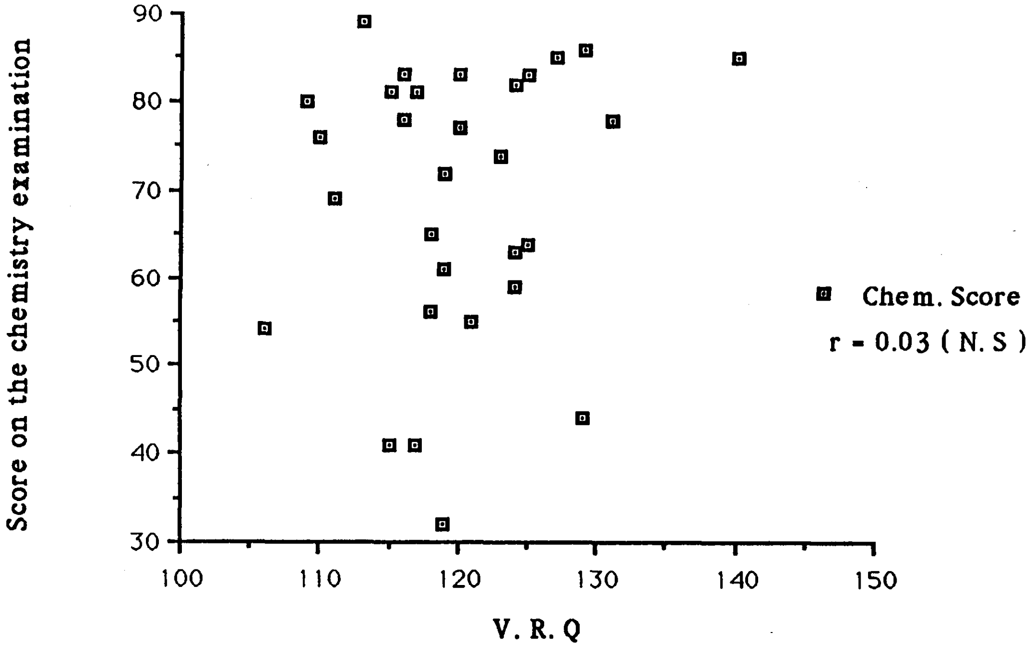
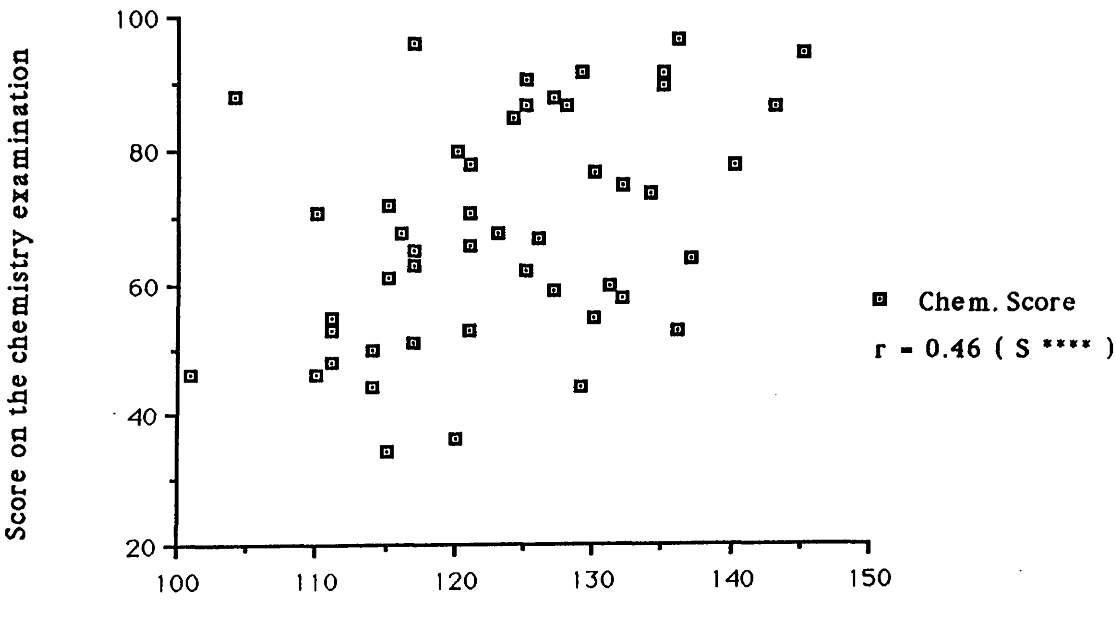


Figure 6.3 The X=6 pupils' attainments in the chemistry examination versus their V. R. Q. score.



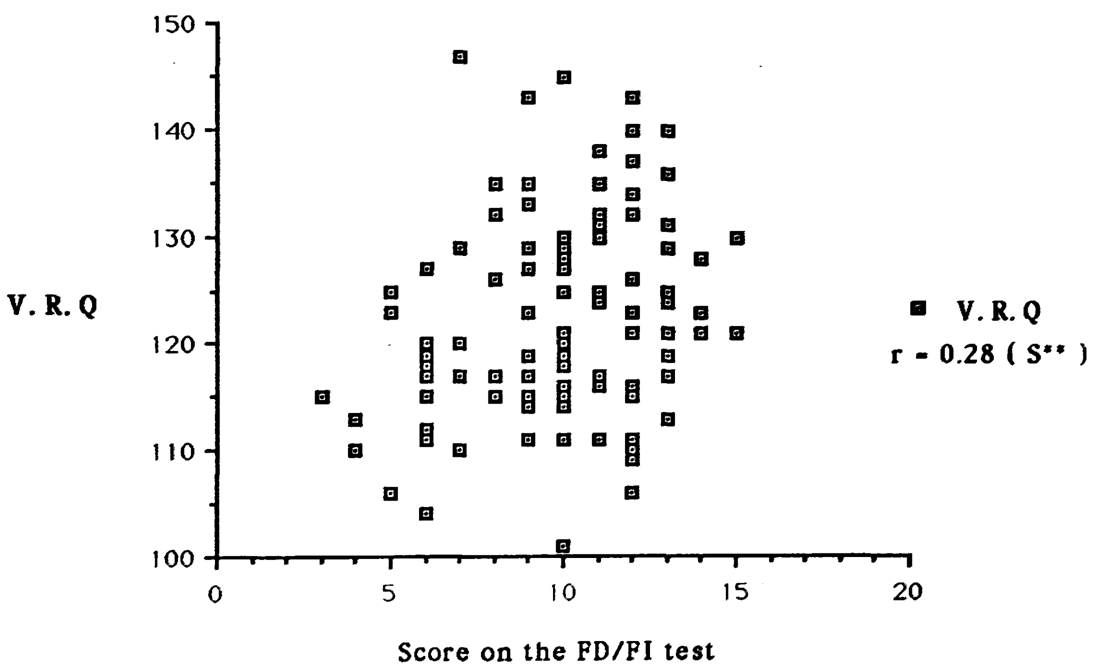
**** Significant at 0.1% level

Figure 6.4 The X=7 pupils' attainments in the chemistry examination versus their V. R. Q. score.

The findings of the previous figure show that the correlation obtained is significant for the X=7 pupils but is not significant for both the X=6 and the X=5 pupils. Therefore, for high capacity pupils, it could be that the V. R. Q. is more important in determining their chemistry scores than it is for medium and low capacity pupils.

6.2.3 'Intelligence' compared with FD/FI

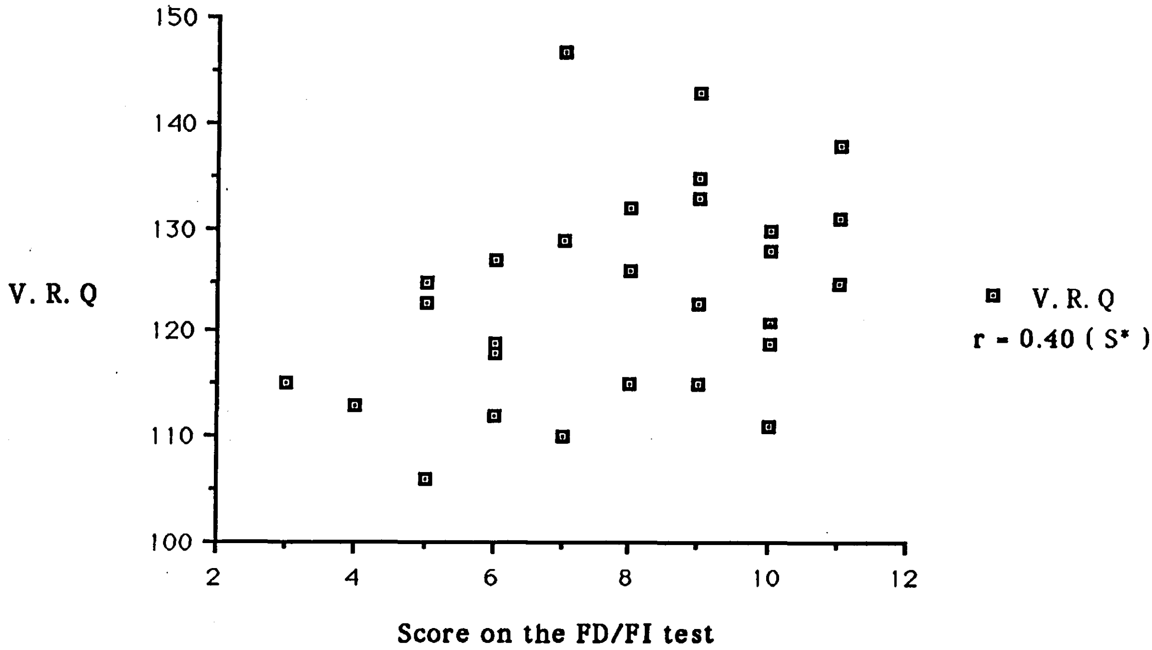
The pupils' V. R. Q. score was plotted against their FD/FI score. The pattern which emerged from that is displayed in figure 6.5.



** Significant at 1% level

Figure 6.5 The pupils' V. R. Q. score against their FD/FI score.

A significant correlation was obtained between the two variables as the Pearson Product-Moment Correlation Coefficient was 0.28 (significant at the 1% level). To find out the correlation between the two variables due to the different groups of X-space, the researcher plotted the pupils' V. R. Q. score against the FD/FI score for each group as shown in figures 6.6, 6.7, and 6.8.



* Significant at 5% level

Figure 6.6 The X=5 pupils' V. R. Q. score versus FD/FI score.

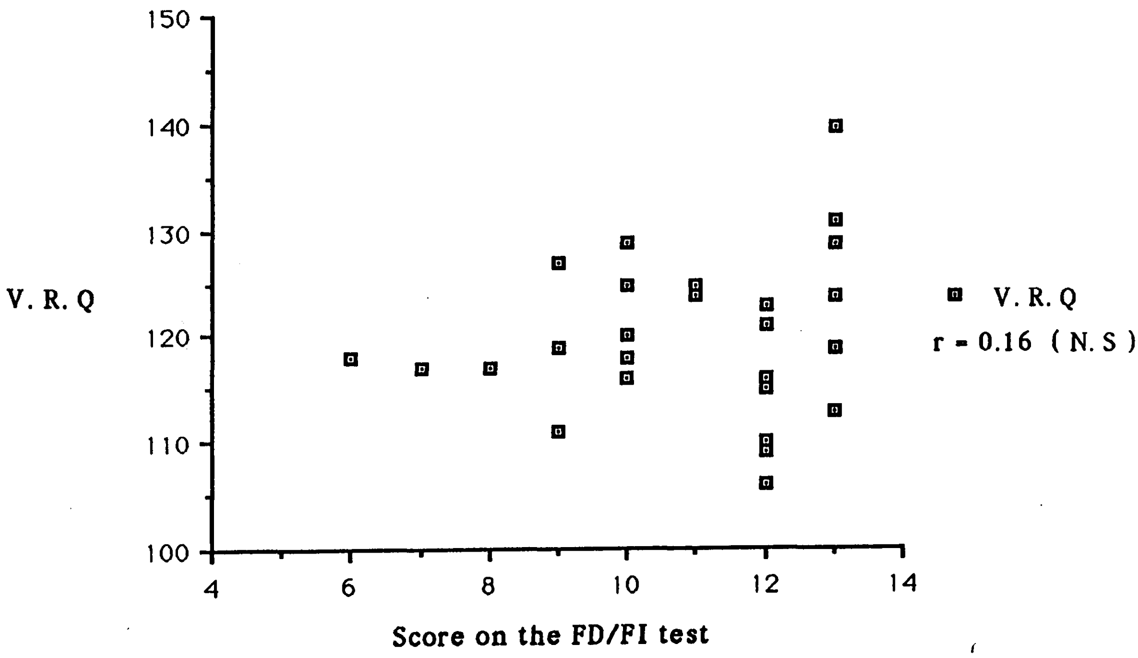
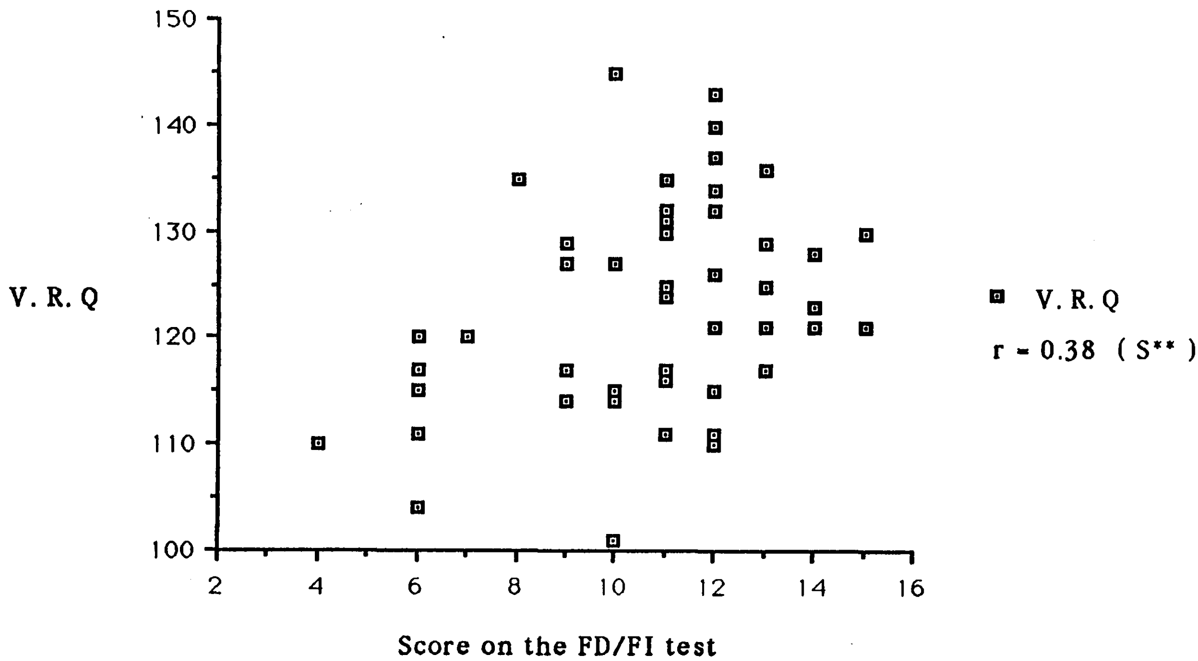


Figure 6.7 The X=6 pupils' V. R. Q. score versus FD/FI score.



** Significant at 1% level

Figure 6.8 The X=7 pupils' V. R. Q. score versus FD/FI score.

The findings obtained from the above results show a significant correlation between the two variables for the X=5 and the X=7 pupils but no significant correlation was obtained between the two variables of the X=6 pupils.

6.3 The X-space compared with FD/FI, and the chemistry scores of the sample

It was stated in the previous chapters that the model of the present hypothesis suggests that there is a correlation between the X-space of the subjects and their degree in FD/FI and the X-space of the pupils versus their attainments in the chemistry examination. The researcher intends to examine the Hucheson's Grammar School sample and exhibit the results to the reader.

6.3.1 The X-space compared with the FD/FI

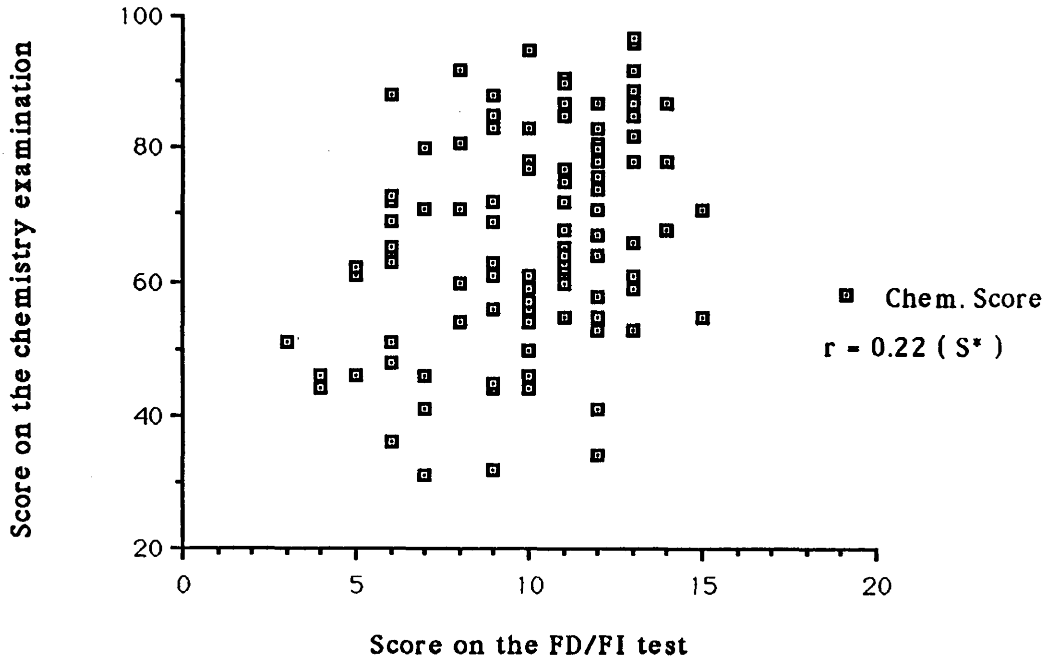
The predictive model of the information processing hypothesis in this study anticipates the existence of a significant correlation between the X-space of the subjects and their FD/FI score. And, indeed, the Pearson Product-Moment Correlation Coefficient which emerged from plotting the pupils' FD/FI scores versus the X-space scores was 0.41 (significant at the 0.1% level).

6.3.2 The X-space measure compared with the chemistry examination

The correlation between the X-space of the subjects and their scores in the chemistry examination must be significant in order to concur with the researcher's expectations. The variable of the pupils' scores in the chemistry examination has been plotted versus the pupils' X-space and a significant correlation emerged as the Pearson Product-Moment Correlation Coefficient was 0.20 and the null hypothesis could be rejected [48] at 5% level.

6.3.3 FD/FI compared with the chemistry examination

A general trend was found in the study that field-independent subjects are more likely to obtain high marks in the chemistry examination than the field-dependent subjects.



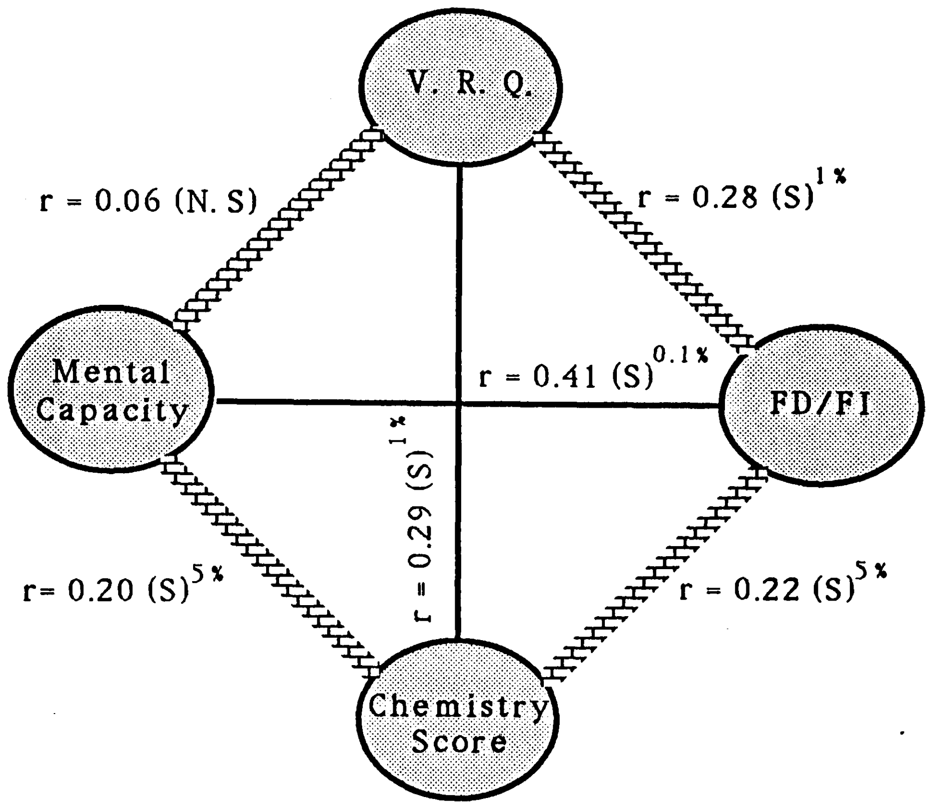
* Significant at 5% level

Figure 6.9 The pupils' degrees attainments in the chemistry examination versus FD/FI score.

The pupils' scores in the chemistry examination have been plotted versus their FD/FI score and a significant correlation emerged as the Pearson Product-Moment Correlation Coefficient was 0.22. The null hypothesis [48] could be rejected at 2% level. Figure 6.9 displays this.

6.4 General trends from this research and indications for further study

The research conducted in the Hucheson's Grammar School is summarised as shown in figure 6.10.



r = Correlation Coefficient

Figure 6.10 The findings of the research among the sample of the Hucheson's Grammar School.

It was found that the holding/thinking space of the subject could affect his performance in a chemistry examination. The subject who has a big X-space may perform better than the others while the subject with a small X-space will tend not perform as well. Moreover, a very significant correlation is found when the X-space plotted versus the degree of FD/FI, which may suggest that, in problem solving, a high X-space subject looks thoroughly at the problem initially and then he easily separates between the 'signal' from the 'noise' (he has enough room in his X-space to handle both the 'signal' and the 'noise'). In other words, the high capacity subjects tend to be field-independent since they have enough room in their X-space to hold and think a bit of irrelevant material as well as relevant materials of the problem. They would, eventually, respond more correctly than the others (to the problem) as the rest of their X-space, which was not occupied by the irrelevant material or 'noise' is sufficient to tackle the problem. Whereas the low X-space subject is not able to separate between the 'signal' from the 'noise' habitually (he has not enough room in his X-space to handle the 'signal' and the 'noise' simultaneously). In brief, the low capacity subjects tend to be field-dependent since the rest of their X-space not captured by the 'noise' is insufficient to tackle the problem.

The correlation which emerges from the subjects' scores in the X-space measurement with their scores in the intelligence test is very low. This is explicable if one considers that each form of test measures something different.

However, 'intelligence' is an important factor in the performance of the subjects in the chemistry examinations since a significant correlation was obtained from drawing a scatter diagram between such variables.

Furthermore, a significant correlation was found between 'intelligence' and FD/FI, which could suggest that a highly intelligent subject seems to think in a field-independent way whereas a subject of low intelligence thinks in a field-dependent way.

The findings of the present study encourage further research in this field to evaluate the intelligence factor and determine its accurate position in the information processing hypothesis. Additionally, on the psychological constructs of capacity, FD/FI and intelligence, it is yet to be investigated which combination would predict chemistry score best? Could a subject with high, X-space, FD/FI and intelligence be the best achiever in the chemistry examination? And, should a subject with low, X-space, FD/FI and intelligence be the worst achiever in such examination?

CHAPTER SEVEN

Conclusion and discussion

7.1 Summary of the findings from this research

This thesis has explored a predictive model based upon information processing theory. The research of this thesis emphasises some aspects which are summarised in the following way:

a - The ability of the student to solve a problem is affected by his holding/thinking space (X-space) which represents an area in the brain where we hold, organise, shape, and consider information.

b - Students can be divided into three groups according to their working memory capacities: the X=5 students who have the smallest X-space to manipulate the tasks with; the X=6 students who have a large X-space than the X=5 students though still not the largest; and the X=7 students who have the largest X-space to manipulate the tasks with and who do so more successfully than the others.

c - According to the model, the questions can be analysed into numbers of thought steps (Z-demand)(complexity).

d - A sudden decline in average performance emerged whenever the complexity of the question exceeded the X-space of the problem solvers, but it did not decline to zero in most of the examples.

e - In solving problems, the learner would fail if the Z-demand (complexity) of the task exceeds his X-space unless he either employs a particular strategy such as breaking the task into sub-tasks by using the technique of 'chunking'. One could generalise that the Z-demand of the task must be equal or less than the X-space of the student to enable him to succeed.

f - This model can predict fairly well the range of the student's achievement in each question in the chemistry examination depending on two factors; the X-space of the learner, and the Z-demand of the question.

g - The research found that high capacity students tend to be field-independent students and at the same time, they have the ability to obtain high marks in conventional chemistry examinations. Low capacity students, on the other hand, tend to be field-dependent students and they obtain lower marks in such examinations.

h - The X-space of field-independent students seems to have enough room to handle both relevant and irrelevant materials, whereas the X-space of the field-dependent students does not have enough room to handle irrelevant material in addition to relevant material. Johnstone states [58] "could it be that students of low working memory space do not have enough space to take on board any irrelevant material? On the other hand, those of large working space may be able to cope, with some of that space occupied by irrelevant information, and still perform satisfactorily".

i - 'Intelligence' emerges as another important factor which affects learning science. It was found that the intelligence factor has no significant relationship with the X-capacity factor while both have a significant relationship with the performance of students in conventional chemistry examinations. It could be that intelligence test tasks may not exceed the X-space of the students and therefore this test must measure some other factor.

j - A significant correlation was obtained from plotting the V. R. Q. score of the students against the FD/FI score.

7.2 Suggestions for further research

During the course of the research recounted in this chapter, it became apparent that many questions raised by the study require solution in further research. The researcher therefore intends to summarise some ideas and suggestions that have arisen without providing clear answers:

a - Concerning the quality and nature of questioning, does a chemistry question have the same effect on students with a certain X-space as the effect of a biology, mathematics, or physics question on such students? It may differ between subjects, and, if so, to what extent does it differ?

b - Further research may well be pertinent on a comparison of the student's FD/FI score with their attainments in different Z-demand questions.

c - What exactly does the intelligence test measure? What is the influence of 'intelligence' on the performance of the students in conventional examinations? What is the relationship between the X-capacity and the 'intelligence'?

d - To what extent does the intelligence factor effect the FD/FI students in their way of thinking?

e - Could the teachers employ the terms of X-space, FD/FI, and 'intelligence' in teaching 'learning strategies'?

f - Are there any other factors which affect the ability of students in solving problems?

7.3 The research's message for the teacher

Due to the character of this study it dealt with the performance of students in both the secondary and tertiary levels of chemistry education based upon an information processing model. It therefore seems reasonable and proper for the present research to conclude in some suggestions for educators which emerged from the study:

a - Teachers ought to re-build and modify their questions in a more exact manner. They should realise that the student's part of the brain which is responsible for processing given information is of a limited size. Accordingly, the student, to solve any question, begins by interpreting the question in his limited working memory capacity to which he then adds any relevant pieces of information from his long-term memory. If the input information is within his limited capacity he may respond correctly, otherwise he may interpret wrongly if the question exceeds his limited capacity [58].

b - Teaching strategies ought to be a very important factor in learning and thus teachers should find some types of strategies which may enable the student to overcome any problems he may encounter. Effort should be channelled towards creating such skills or strategies which teachers can then provide students with to enable them to tackle further work more successfully.

c - Teachers should realise that questions with high Z-demand are measuring both the X-space and the subject matter. However, if the student has developed good Y-strategies he may do well but the teacher does not know whether this success is due to high capacity or efficient chunking or knowledge of the subject.

d - Teachers ought to educate students in a strategy of how to organise information in their minds and how to separate relevant from irrelevant information as what is irrelevant may interfere with designated tasks.

e - 'Chunking' is a very beneficial technique in the predictive model of the information processing theory. Teachers could re-organise their materials in a way which would facilitate the learning. In other words, teachers must present their materials in small portions and in a well-organised way to enable students to develop concepts, later problems can be set where the Z-demand less than the X-space of the student so that the technique of chunking can be taught.

REFERENCES

1. Wadsworth, B. J. Piaget's Theory of Cognitive Development (2nd edit.). New York: Longman Inc., 1979.

2. Kagan, J. Understanding Children, Behaviour, Motives, and Thought. New York: Harcourt Brace Jovanovich Inc., 1971.

3. Beard, R. M. An Outline of Piaget's Developmental Psychology for Students and Teachers. London: Routledge and Kegan Paul, 1969.

4. Boyle, D. G. A Student's Guide to Piaget. Oxford: Pergamon Press, 1969.

5. Child, D. Psychology and the Teacher (4th edit.). London: Cassel Educational Ltd., 1986.

6. Donaldson, M. Children's Minds. London: Croom Helm, 1978.

7. Ausubel, D. P. The transition from concrete to Abstract cognitive functioning, theoretical issues and implications for education. Journal of Research in ScienceTeaching, 1964, **2(3)**, 261-266.

8. Novak, J. D. An alternative to Piagetian psychology for science and mathematics education. Studies in Science Education, 1978, **5**, 1-30.

9. Ausubel, D. P. et al. Educational Psychology (2nd edit.). New York: Holt, Rinehart and Winston Inc., 1978.

10. West, L. H. T. & Fensham, P. J. Prior knowledge and the learning of science. Studies in Science Education, 1974, **1**, 61-81.

11. Ausubel, D. P. & Robinson, F. G. School Learning. New York: Holt, Rinehart and Winston Inc., 1969.

12. Novak, J. D. Application of advances in learning theory and philosophy of science to the improvement of chemistry teaching. Journal of Chemical Education, 1984, **61(7)**, 607-612.

13. Novak, J. D. et al. Interpretation of research findings in terms of

Ausubel's theory and implications for science education. Science Education, 1971, **55**, 483-526.

14. Novak, J. D. The reception learning paradigm. Journal of Research in Science Teaching, 1979, **16(6)**, 481-488.

15. Ausubel, D. P. The Psychology of Meaningful Verbal Learning. New York: Grune & Stratton Inc., 1963.

16. Ausubel, D. P. Reading in School Learning. New York: Holt, Rinehart and Winston Inc., 1969.

17. Case, R. Structures and Strictures, some functional limitations on the course of cognitive growth. Cognitive Psychology , 1974, **6**, 544-573.

18. Pascual-Leone, J. A mathematical model for the transition rule in Piaget's developmental stages. Acta Psychologica, 1970, **32**, 301-345.

19. Pascual-Leone, J. The encoding and decoding of symbols by children, a new experimental paradigm and a Neo-Piagetian model. Journal of Experimental Child Psychology, 1969, **8**, 328-355.

20. Case, R. & Serlin, R. A new processing model for predicting performance on Pascual-Leone's test of M-space. Cognitive Development, 1979, **11**, 308-326.

21. Case, R. Mental strategies, Mental capacity, and instruction: A Neo-Piagetian investigation. Journal of Experimental Child Psychology, 1974, **18**, 382-297.

22. Niaz, M. Relation between M-space of students and M-demand of different items of general chemistry and its interpretation based upon the Neo-Piagetian theory of Pascal-Leone. Journal of Chemical Education, 1987, **64(6)**, 502-505.

23. Niaz, M. The information-processing demand of chemistry problems and its relation to Pascual-Leone's functional M-capacity. International Journal of Science Education, 1988, **10(2)**, 231-238.

24. Howe, M. J. A. Introduction to Human Memory. New York: Harper & Row, 1970.

25. Sanford, A. J. The Mind of Man. Brighton, Sussex, The Harvester Press Limited, 1987.

26. Bourne, L. F. et al. Cognitive Processes (2 nd edit.). New Jersey: Prentice-Hall, 1986.

27. Stewart, J. H. & Atkin, J. A. Information processing psychology: A promising paradigm for research in science teaching. Journal of Research in Science Teaching, 1982, **19(4)**, 321-332.

28. Dworetzky, J. P. Psychology (2nd edit.). U. S. A.: St Paul, MN West Publishing Company, 1985.

29. Grogono, P. & Nelson, S. H. Problem Solving and Computer Programming. Reading Mass, Addison-Wesley, 1982.

30. Miller, G. A. The magical number seven, plus or minus two, some limits on our capacity for processing information. The Psychological Review, 1956, **18**, 81-97.

31. Gilhooly, K. J. Thinking, Directed, Undirected and Creative. London: Academic Press Inc., 1982.

32. Johnstone, A. H. New stars for the teacher to steer by? Journal of Chemical Education, 1984, **61(10)**, 847-849.

33. Baddeley, A. Working Memory. Oxford Psychology Series No. 11. Oxford, Clarendan: Oxford University Press, 1986.

34. White, R. T. Achievement, Mastery, Proficiency, Competence. Studies in Science Education, 1979, **6**, 1-22.

35. Anderson, J. R. The Architecture of Cognition. London: Harvard University Press, 1983.

36. Greene, J. Memory, Thinking and Language. London: Methuen & Co. Ltd., 1987.

37. Johnstone, A. H. & Kellett, N. C. Learning difficulties in school science towards a working hypothesis. European Journal of Science Education, 1980, **2(2)**, 175-181.

38. Simon, H. A. How big is a chunk? Science, 1974, **183**, 482-487.

39. Barber, P. J. Applied Cognitive Psychology. London: Methuen & Co. Ltd., 1988.

40. Johnstone, A. H. Chemical educational research, facts, findings, and consequences. Chemical Society Reviews, 1980, **9, 365. (3)**, 365-380.

41. Johnstone, A. H. & Wham, A. J. B. The demands of practical work. Education in Chemistry, 1982, **19(3)**, 71-73.

42. Johnstone, A. H. & El-Banna, H. "Capacities, demands and processes - a predictive model for science education. Education in Chemistry, 1986, **23(3)**, 80-84.

43. Scardamalia, M. Information processing capacity and the problem of Horizontal Decalage: A demonstration using combinatorial reasoning tasks. Child Development, 1977, **48**, 28-37.

44. Claxton, G. Growth Points in Cognition. London: Routledge, 1988.

45. Worth, W. & Schlosberg Experimental Psychology. New York: Methuen, 1950. (First published in U. S. A. 1938).

46. Johnson, J. M. The Figure Intersection Test (FIT): A measure of mental (M) attentional energy. Unpublished manuscript, York University (Ontario), 1982.

47. Kellet, N. C. Studies on the Perception of Organic Chemical Structures. Ph. D. Thesis, University of Glasgow, 1978.

48. Greene, J. & D'Oliveira, M. Learning to Use Statistical Tests in Psychology. Philadelphia: Open University Press, 1982.

49. Witkin, H. A. Cognitive Styles in Personal and Cultural Adaptation. Worcester, Mass.: Clark University press, 1978.

50. Witkin, H. A. et al. Psychological differentiation-Studies of Development. New York : Wiley, 1974.

51. Goodenough, D. R. & Karp, S. A. Field dependence and intellectual functioning. Journal of Abnormal and Social Psychology, 1961, **63**(2), 241-246.

52. Goodenough, D. R. The role of individual differences in field independence as a factor in learning and memory. Psychological Bulletin, 1976, **83**(4), 675-694.

53. Davis, J. K. & Frank, B. M. Learning and memory of field independent-dependent individuals. Journal of Research in Personality, 1979, **13**, 469-479.

54. Case, R. & Globerson, T. Field independence and central computing space. Child Development, 1974, **45**, 772-778.

55. Frank, B. M. Encoding and external-storage effects of personal lecture notes, skeletal notes, and detailed notes for field-independent and field-dependent learners. Journal of Educational Research, 1988, **81**(3), 143-148.

56. Frank, B. M. Flexibility on information processing and the memory of field-independent learners. Journal of Research in Personality, 1983, **17**, 89-96.

57. El-Banna, H. A. A. M. The Development of A Predictive Theory of Science Education Based Upon Information Processing Theory. Ph. D. Thesis, University of Glasgow, 1987.

58. Johnstone, A. H. Meaning Beyond Readability. Guildford: Southern Examining Group, 1988.

APPENDICES

Appendix 1

DIGIT SPAN TEST

The following tests, Digit Forward and Digit Backward, are administered separately. for both, say the digits at the rate of one per second, not grouped. Let the pitch of voice drop with the last digit of each series. The series denotes the number of digits in an item.

Digit Forward

Directions - Start by saying -

"In a fairly simple game, I'm going to say some numbers. Listen carefully to them, and when I stop speaking you write them down in the space provided in the sheet that you have been given.

Are you ready then? Let us begin."

Series :

3	5	8	2						
	6	9	4						
4	6	4	3	9					
	7	2	8	6					
5	4	2	7	3	1				
	7	5	8	3	6				
6	6	1	9	4	7	3			
	3	9	2	4	8	7			
7	5	9	1	7	4	2	8		
	4	1	7	9	3	8	6		
8	5	8	1	9	2	6	4	7	
	3	8	2	9	5	1	7	4	
9	2	7	5	8	6	2	5	8	4
	7	1	3	9	4	2	5	6	8

Appendix 1 (cont'd)

Digits Backward

Directions - Start by saying -

" Now I'm going to give another set of numbers, but this time there's a complication. When I've finished saying each set of numbers, I want you to write them down in reverse order. For example, if I say, "719", you would write down 917. Now, no cheating. Do not write from right to left. You listen carefully, turn the number over in your mind and write from left to right. Have you got that? Then let's begin."

series :

2	2 4
	5 8
3	6 2 9
	4 1 5
4	3 2 7 9
	4 9 6 8
5	1 5 2 8 6
	6 1 8 4 3
6	5 3 9 4 1 8
	7 2 4 8 5 6
7	8 1 2 9 3 6 5
	4 7 3 9 1 2 8
8	9 4 3 7 6 2 5 8
	7 2 8 1 9 6 5 3

Appendix 1 (cont'd)

NAME :

SEX :

DATE OF BIRTH :

DIGIT FORWARD

Series	NUMBERS								
3									
4									
5									
6									
7									
8									
9									

DIGIT BACKWARD

Series	NUMBERS							
2								
3								
4								
5								
6								
7								
8								

Appendix 2 (a)

*FIGURE INTERSECTION TEST

NAME : SEX :

SCHOOL : DATE OF BIRTH :

CLASS :

This a test of your ability to find the overlap of a number of simple shapes.

There are two sets of simple geometric shapes, one on the right and the other on the left. The set on the right contains a number of shapes separated from each other.

The set on the left contains the same shapes (as on the right) but overlapping, so that there exists a common area which is inside all of the shapes.

Look for and shade in the common area of overlap.

Note these points:-

(1) The shapes on the left may differ in size or position from those on the right, but, they match in shape and proportions.

(2) In some items on the left some extra shapes appear which are not present in the right hand set, and which do not form a common area of intersection with all of the other shapes. These are present to mislead you but try to ignore them.

(3) The overlap should be shaded clearly by using a pen.

(4) The results of this test will not affect your schoolwork (university work) in any way.

---

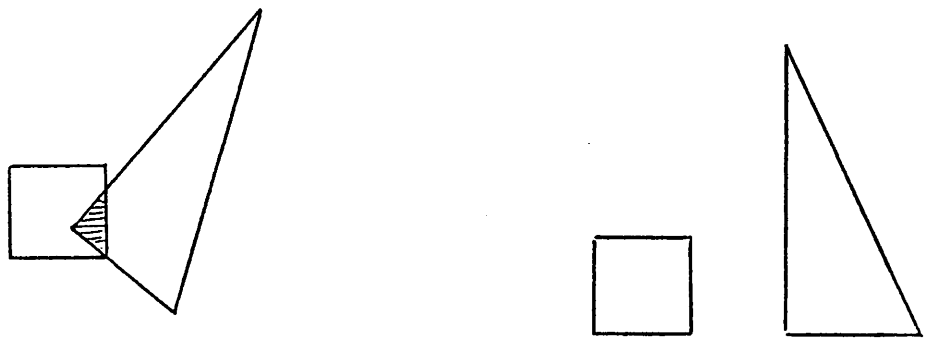
* This test may not be used without permission from: Professor J. Pascual-Leone, Room 246 B. S. B., York University, 4700 Keele Street, Downsview, Ontario, M3J 1P3.

* This test is photo-reduced to fit the pages of this thesis.

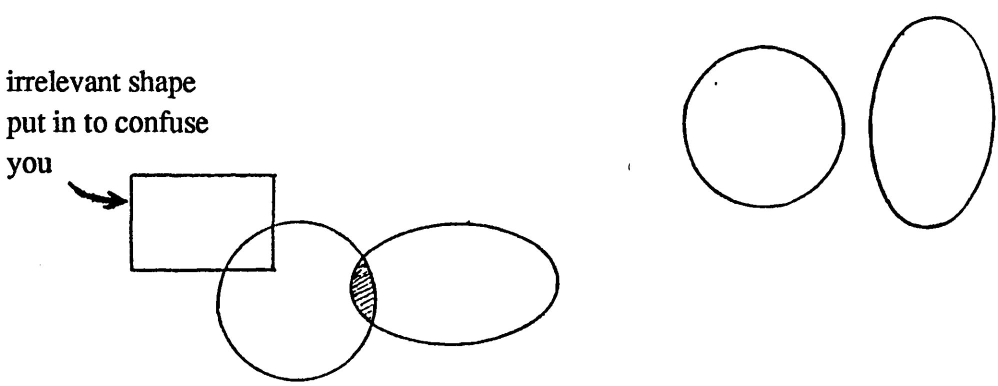
Appendix 2 (a) (cont'd)

Here are some examples to get you started.

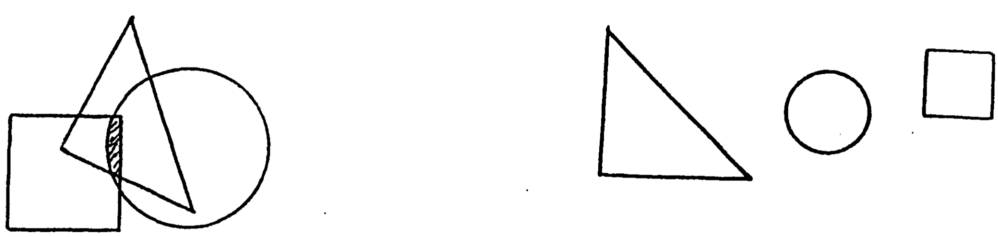
Example (1)



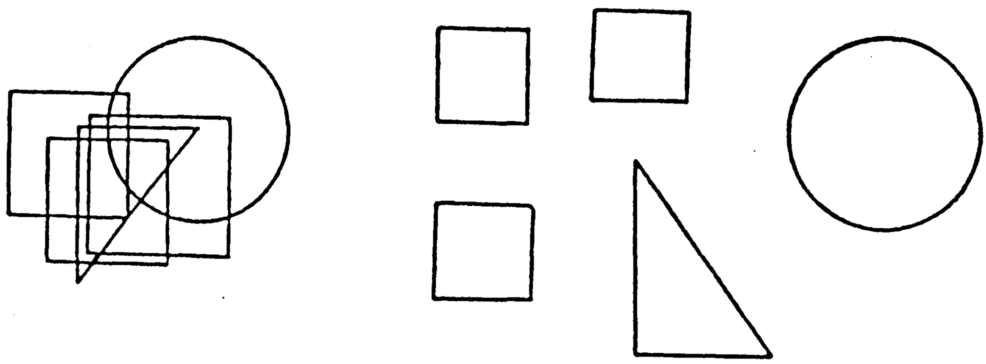
Example (2)

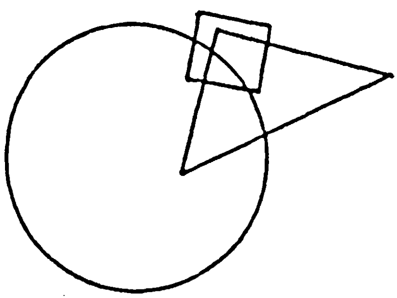


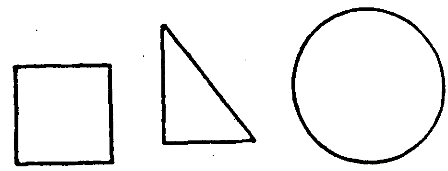
Example (3)

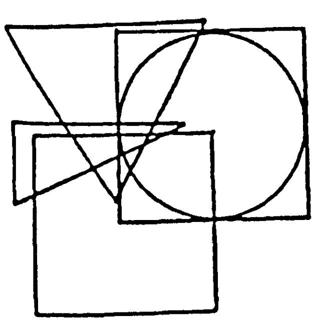


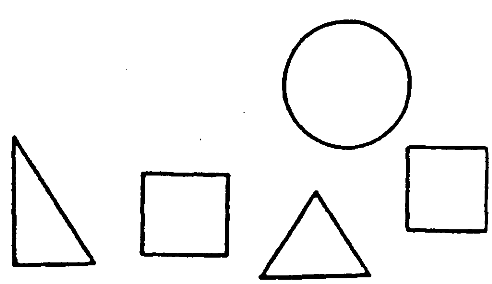
Now attempt each of the items on the following sheets.

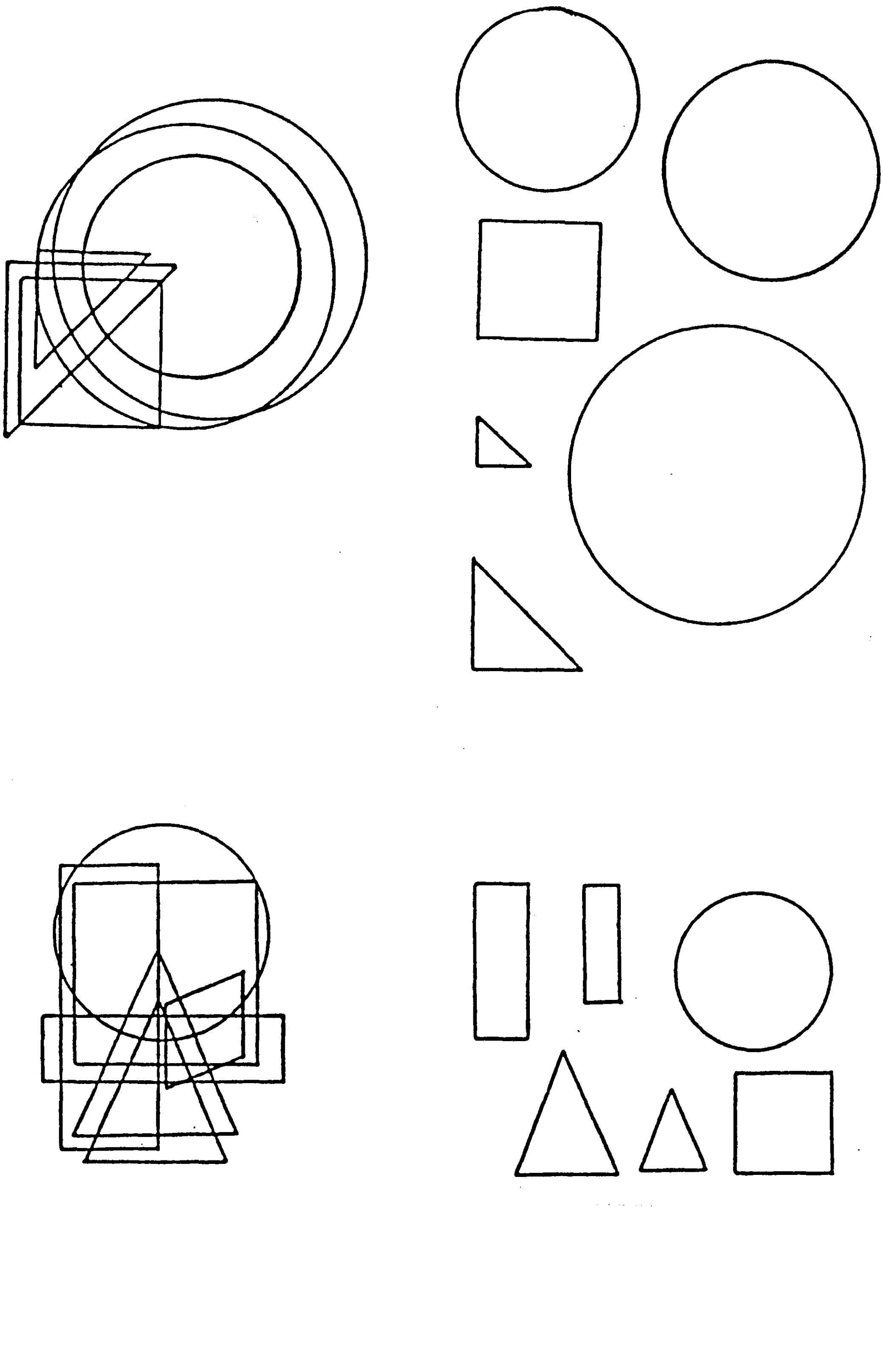


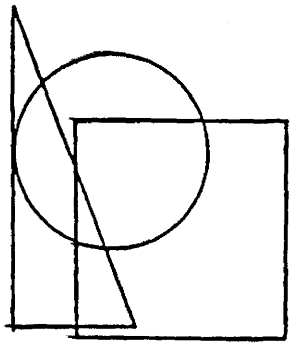


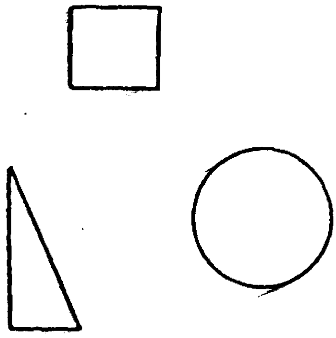


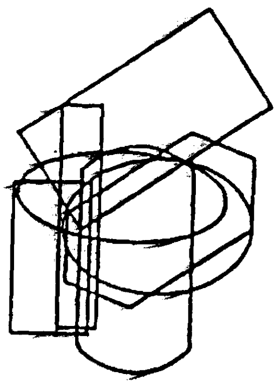


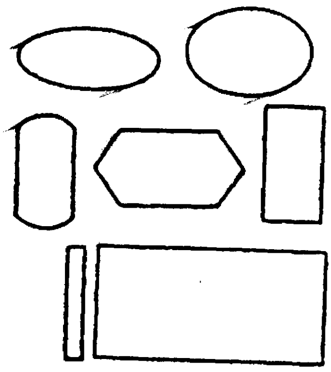


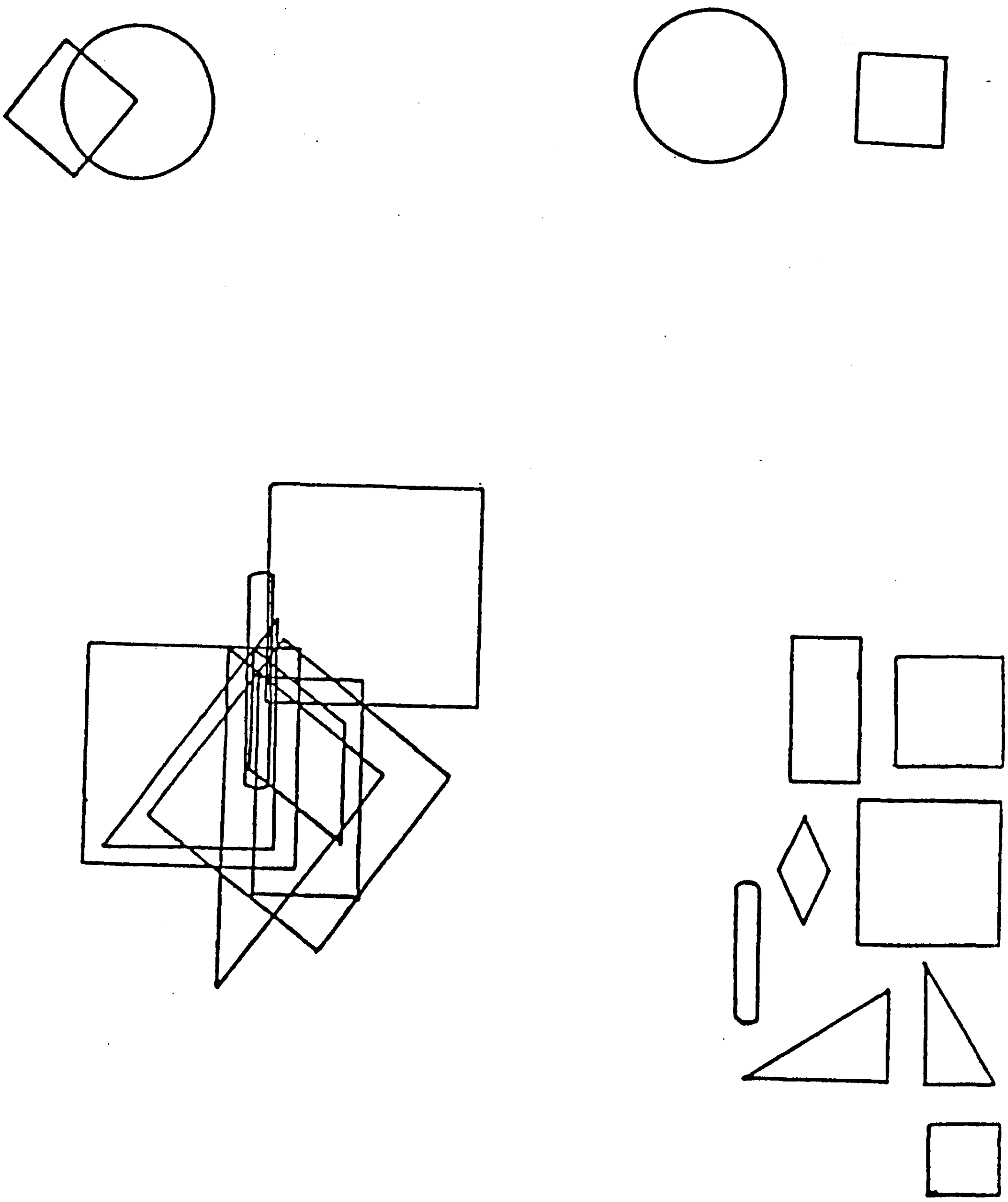


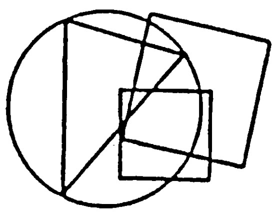


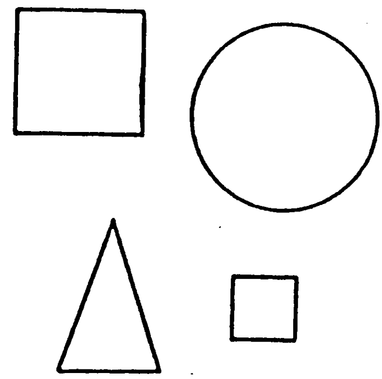


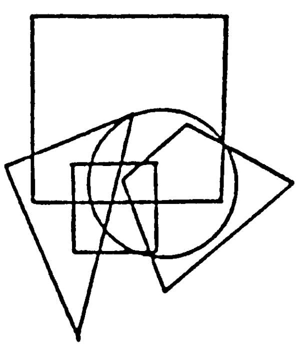


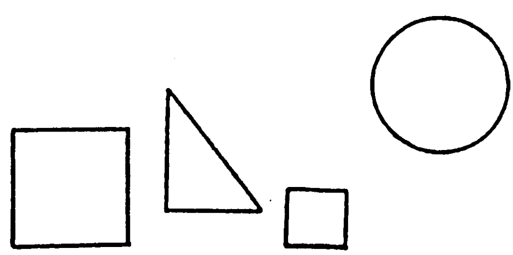


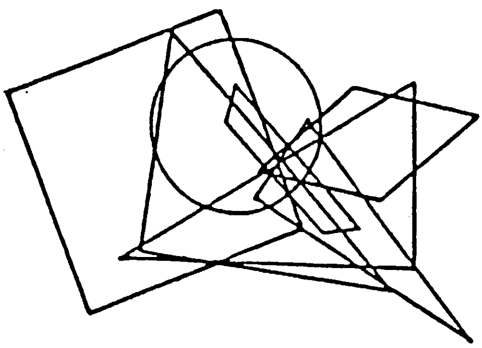
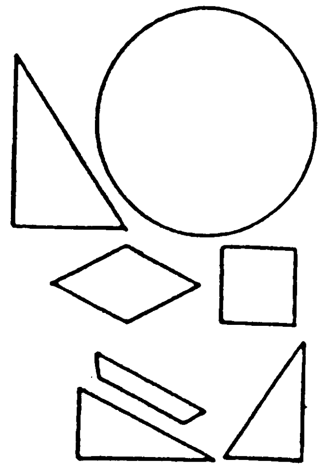
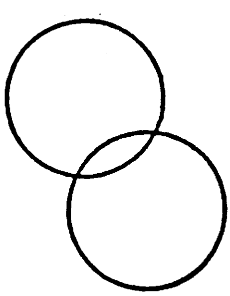
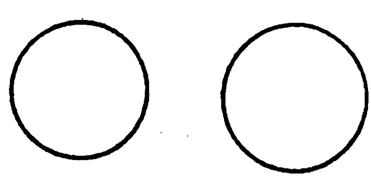


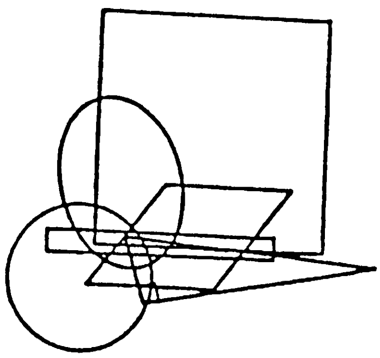


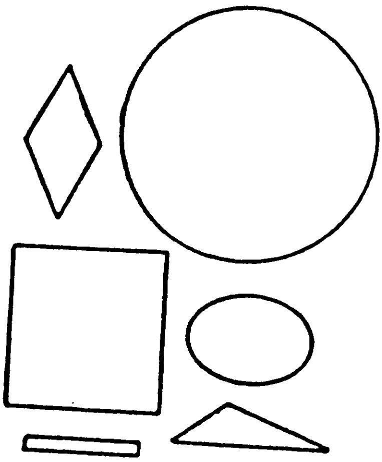


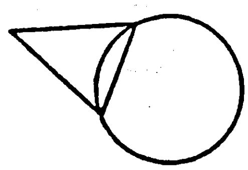


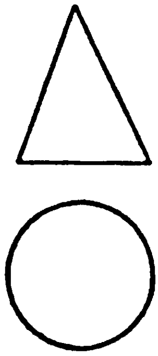


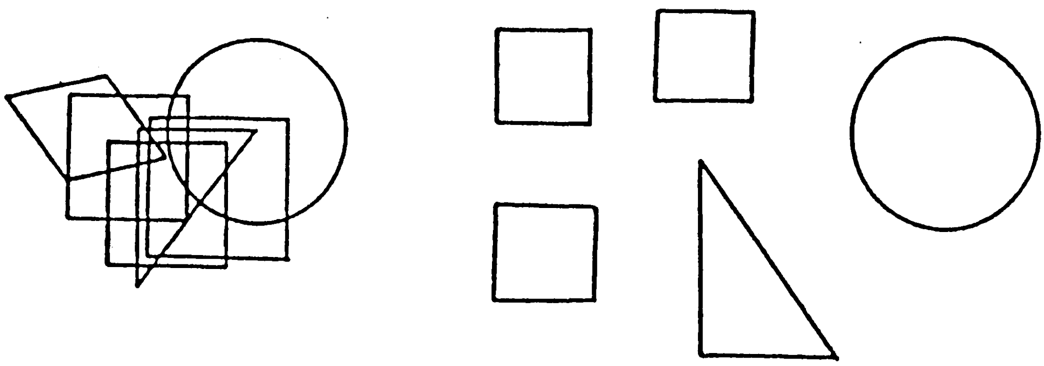





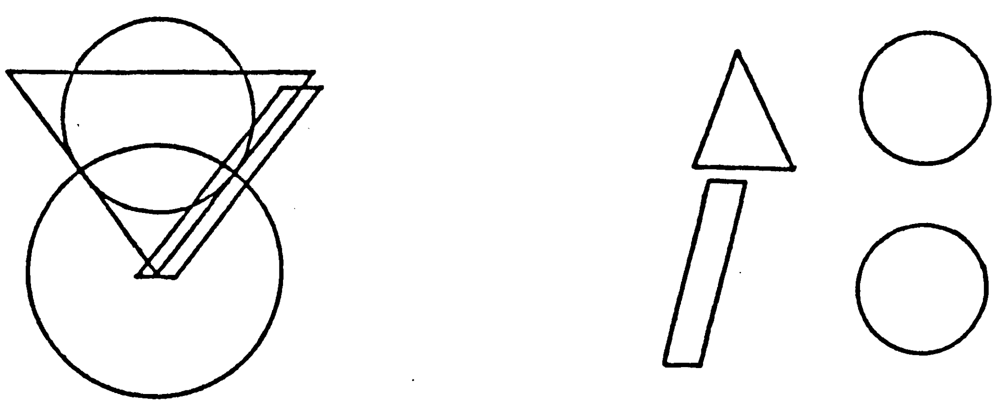


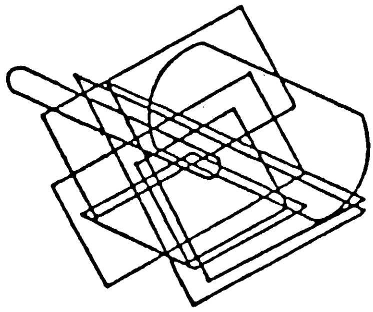


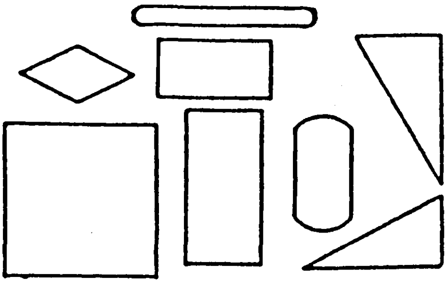


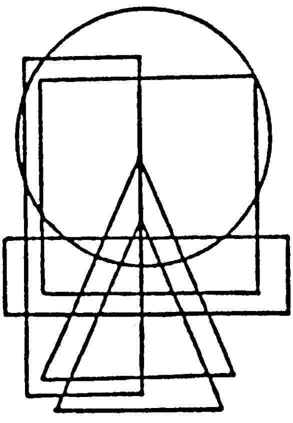


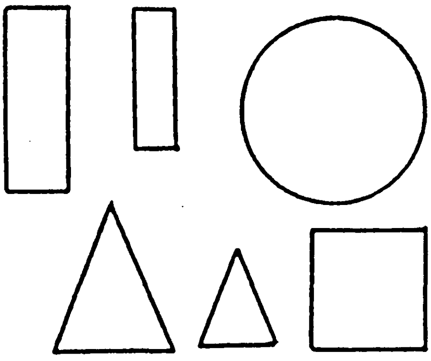


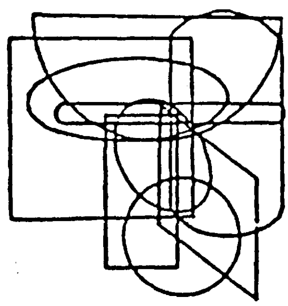


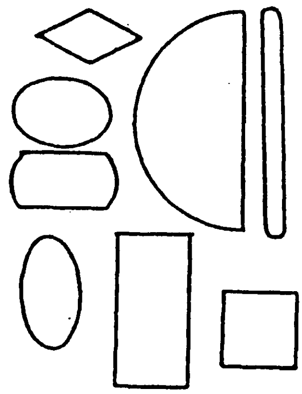


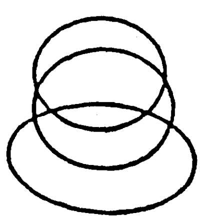


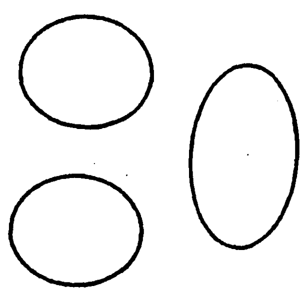


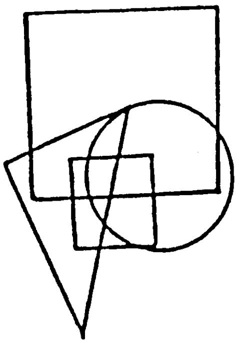


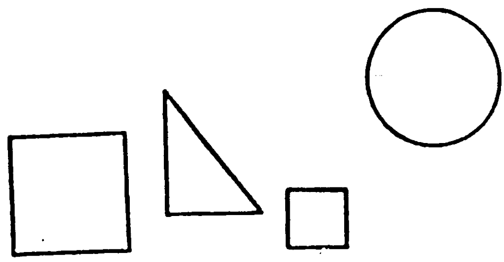


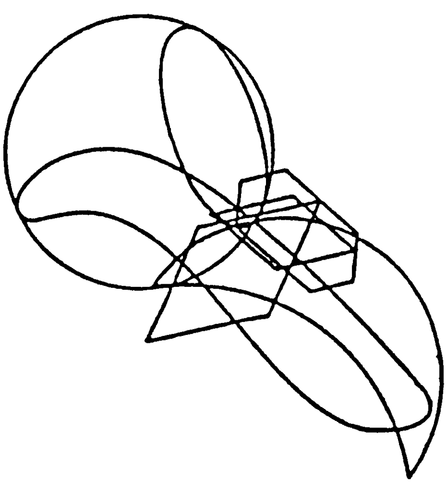


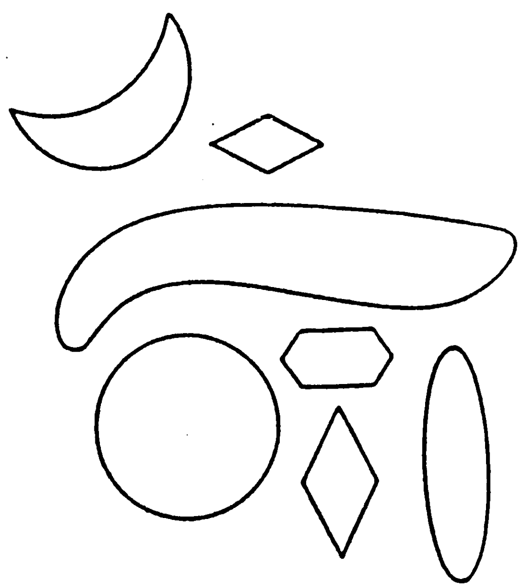


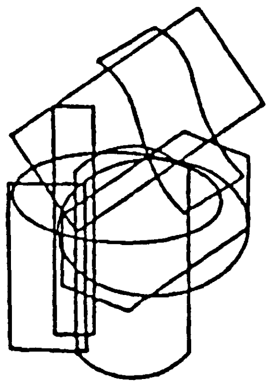


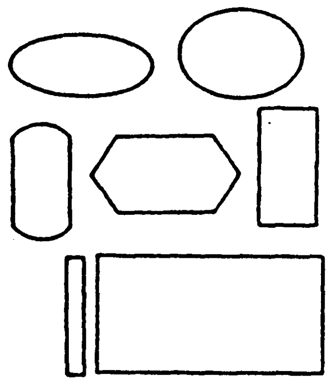


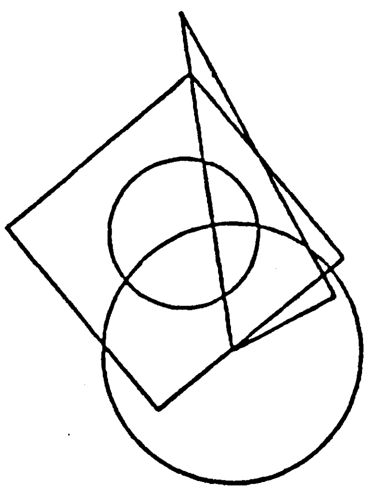


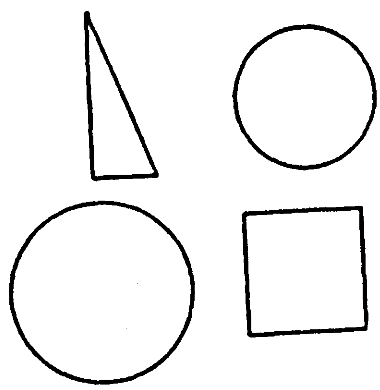


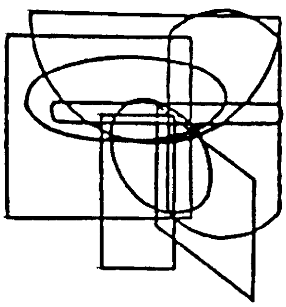


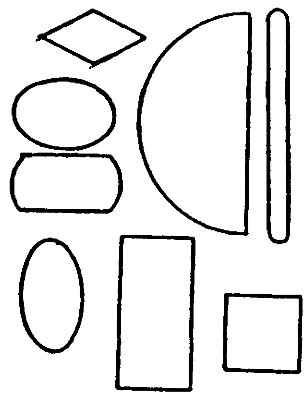


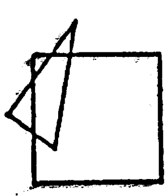


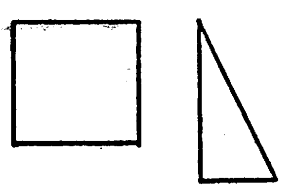


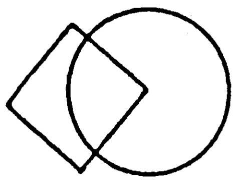


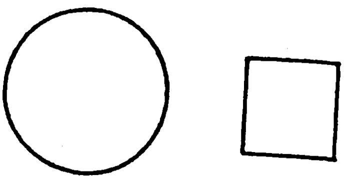


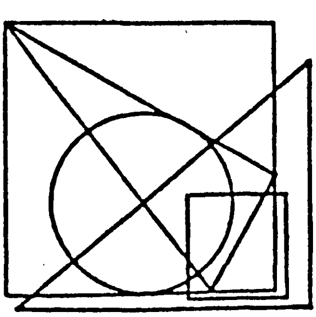


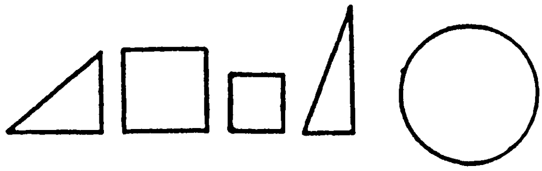


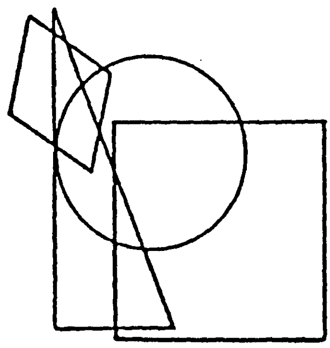


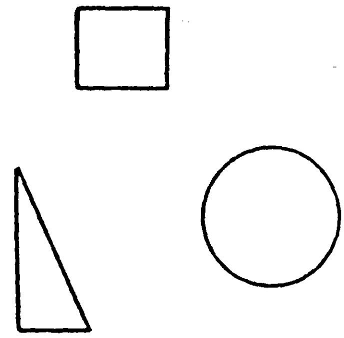


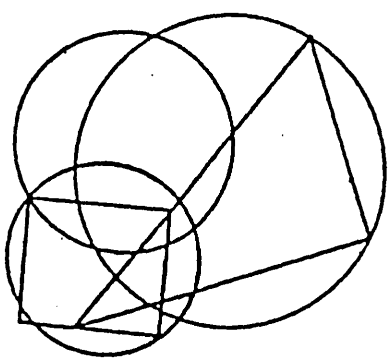


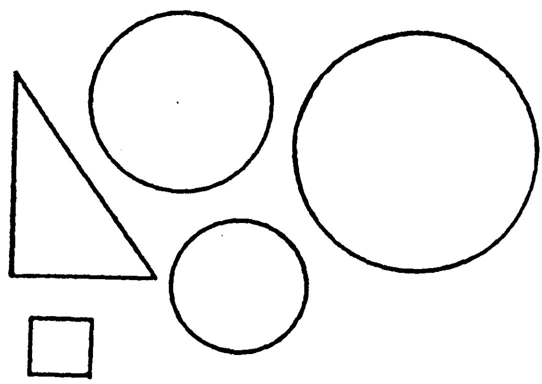


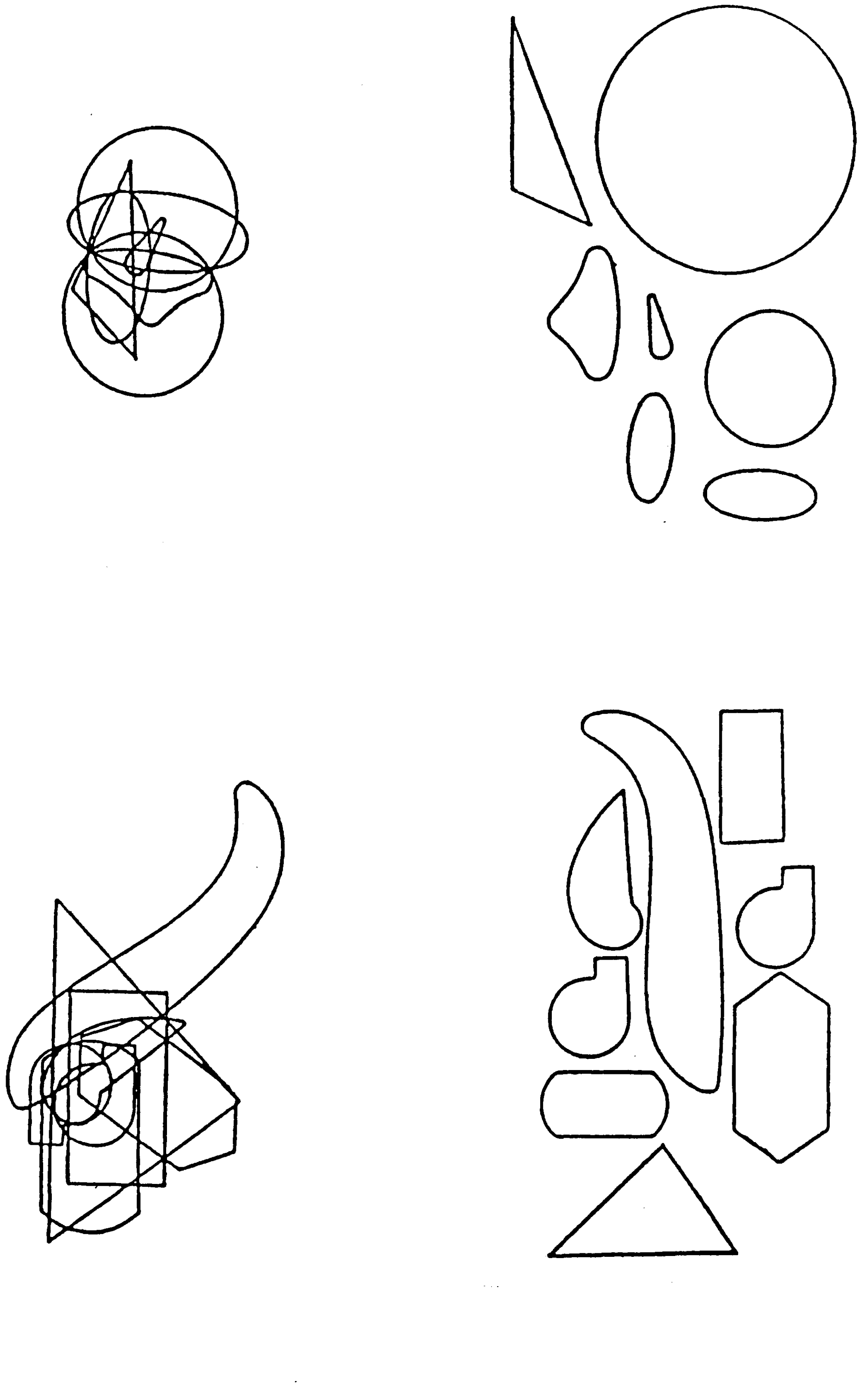


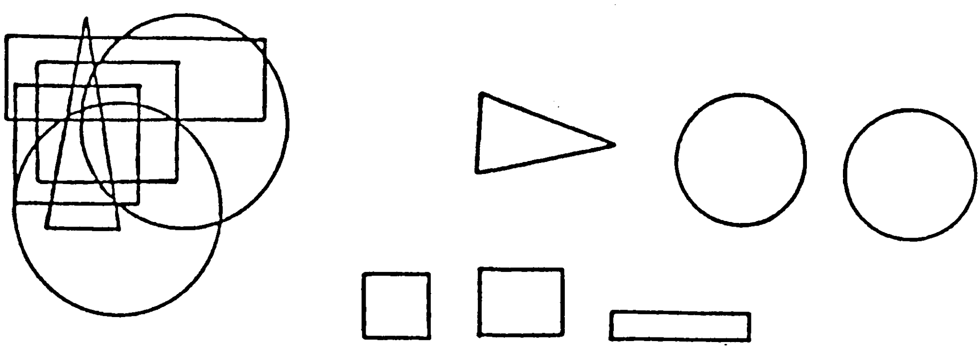


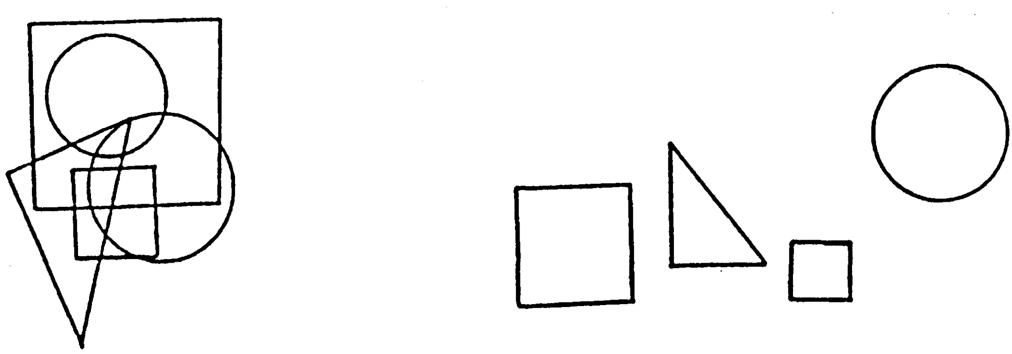












Appendix 2 (b)

ASSIGNMENT OF k ESTIMATES ON THE BASIS OF FIT PERFORMANCE

Four k scores were initially assigned to each subject on the basis of his/her FIT performance; a single k score was then computed for each subject based on the four scores. Each item class in the FIT version used (except class 2) contained at least one item with an irrelevant figure: the irrelevant figure appeared in the compound-form set but not in the discrete set for the item. In grouping items into classes, items with X relevant figures and one irrelevant figure may either be put into class X or into class X + 1, depending or whether or not one assumes that the irrelevant figure adds to task demand (i. e. Md of item = X or X + 1). The strategy of placing items with X + 1 figures in the compound into class X has typically been used in scoring the FIT. however, there is some evidence that items with an irrelevant shape in the compound actually have an Md of X + 1.

In the present study scores was computed for each of the two ways of classifying items. These two ways of grouping items into classes are referred to as X scaling (X relevant + 1 irrelevant = class X) and X + 1 scaling (X relevant + 1 irrelevant = class X + 1).

Two kinds of k scores were computed for each way of scaling the item classes. One kind of score was the $k_{.75}$ scores which repeatedly has been found to provide k estimates close to theoretically-appropriate values. This score is obtained by grouping the items into classes and obtaining for each class the percentage of items passed in that class. The $k_{.75}$ score is the highest stimulus class at which at least 75% of the items are passed, provided that all (or all but one) of the lower classes also have 75% pass rates (a drop to 60% pass in one lower class is allowed). (This score is sometimes referred to as the $k_{.80}$ score, however, given the number of items in each FIT class, there is no practical difference between using a pass rate of 75% and one of 80%). This way of scoring yielded two scores: $\underline{k}_{.75}$ - X and $\underline{k}_{.75}$ - X + 1.

The second kind of k score is the SI-theoretical (or SIT) score. This score is based on the strong theoretical assumption that a child will solve all and only those items with class values less than or equal to his/her Mp (e. g. if a child has an Mp of 3, she/he should solve all class 2 and 3 items, but no items of class 4 or higher). The score is computed by first summing the number of items solved across stimulus

classes 2 through 7. One then uses a raw-score distribution to determine what SIT score corresponds to the (summed) raw performance score. Table A. 4. 1 lists the distributions for assigning SIT scores for the X and X + 1 scaling methods for the FIT version and in the present study. (The distributions were constructed based on the strong theoretical assumption stated above). L call the SIT scores SIT - X and SIT - X + 1.

Pascual-Leone suggests that the SIT score may be more reliable, because it is based on data from all the passed items. The $\underline{k}_{.75}$ score, however, may be more valid, because it is sounder semantically, pegging k at the highest item class that is reliably passed. A single composite FIT - k score for each subject was constructed in the following manner. The four k-estimates for the subject were examined, and if at least three of the four scores had the same value then that majority value was assigned as the FIT - k score (e. g. scores of 3, 3, 3, and 4 yielded a FIT - k of 3). If there was no majority score value, then the mean of the four scores was assigned as the FIT - k score (e. g. scores of 2, 2, 3, 4 yielded a FIT - k of 2.75); decimal values were retained.

Appendix 2 (b) (cont'd)

Table A. 4. 1.

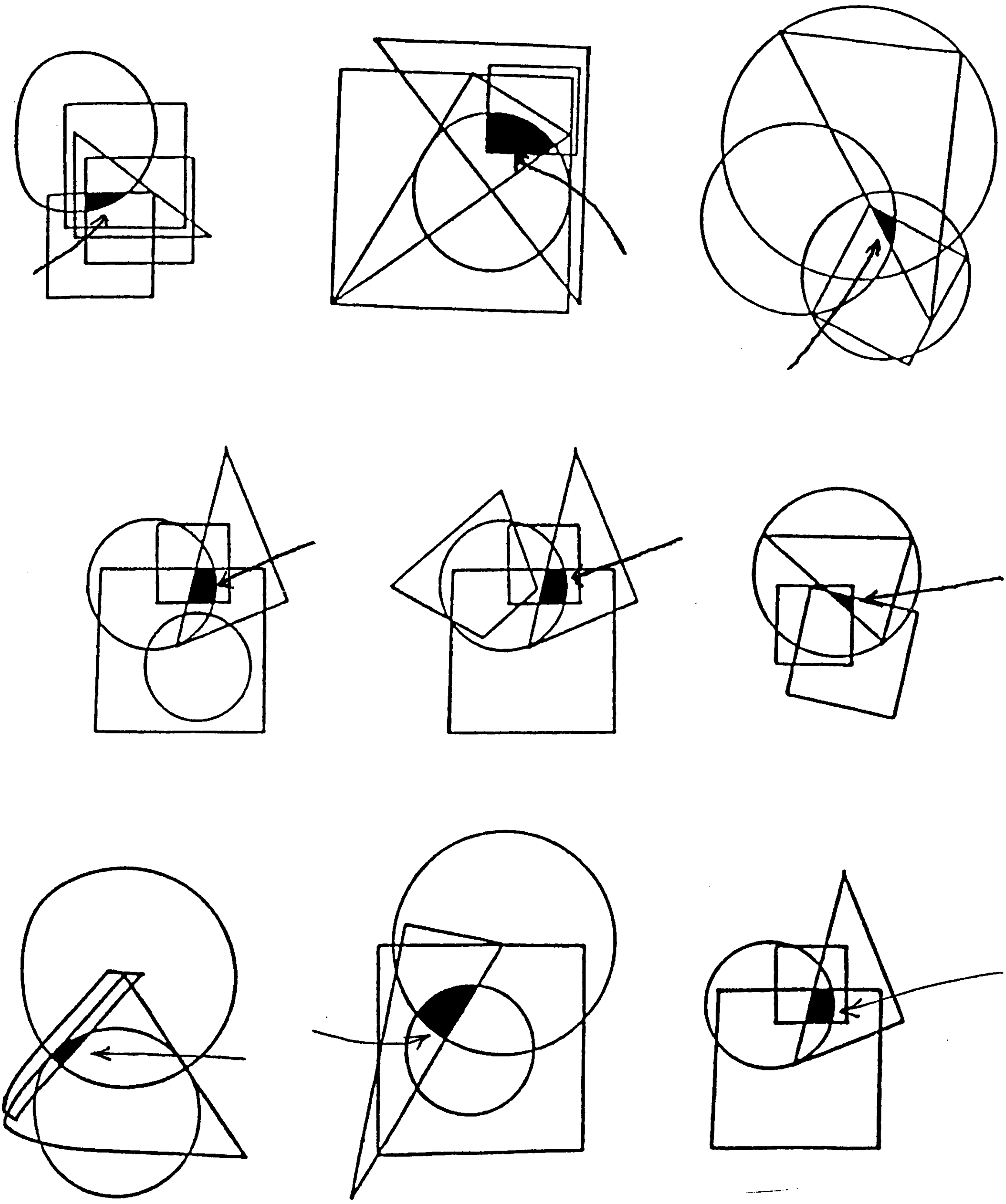
Raw score distributions for assignment of SIT scores on the basis of FIT (RAC 794) performance

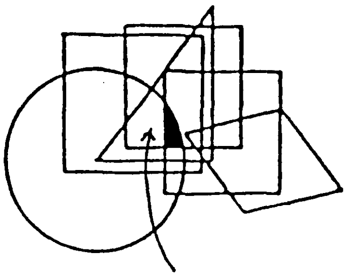
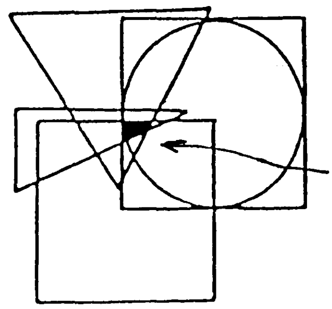
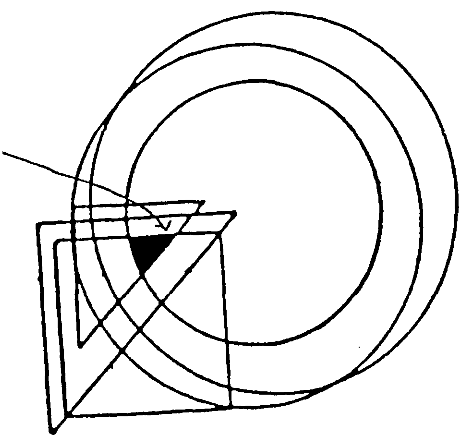
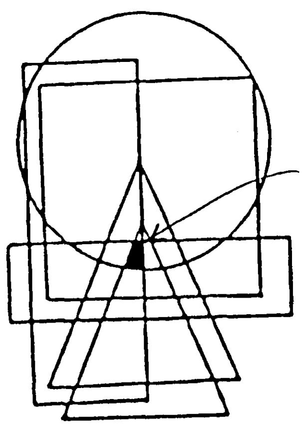
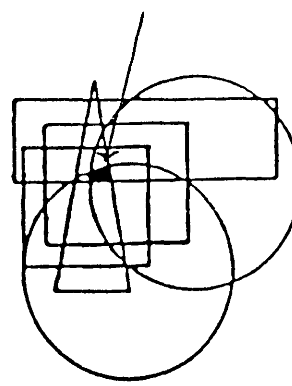
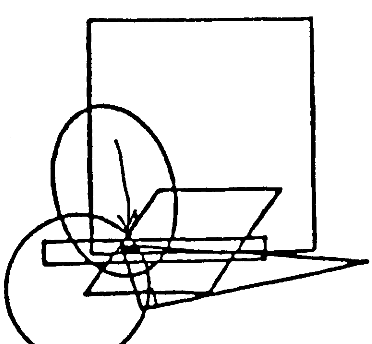
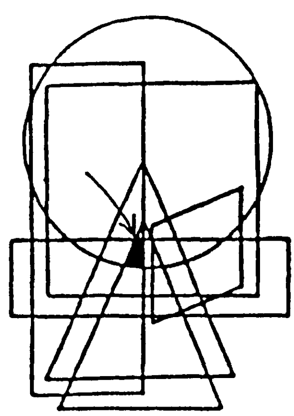
SIT	Number of Correct Items (Classes 2 through 7)	
	X scaling	X + 1 scaling
1	4	4
2	5 - 9	5 - 8
3	10 - 15	9 - 13
4	16 - 20	14 - 19
5	21 - 15	20 - 14
6	26 - 30	25 - 29
7	equal or > 31	equal or > 30

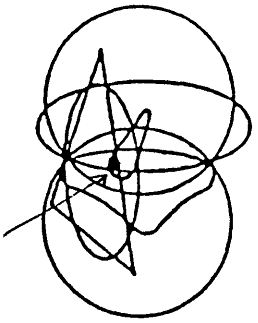
Extracted from Ref. No. [45].

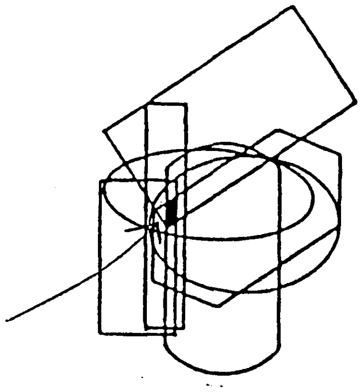
Appendix 2 (c)

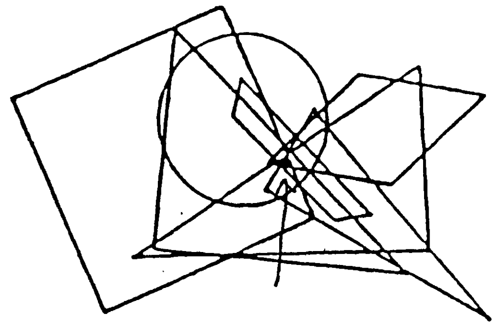
F. I. T. Scoring Key

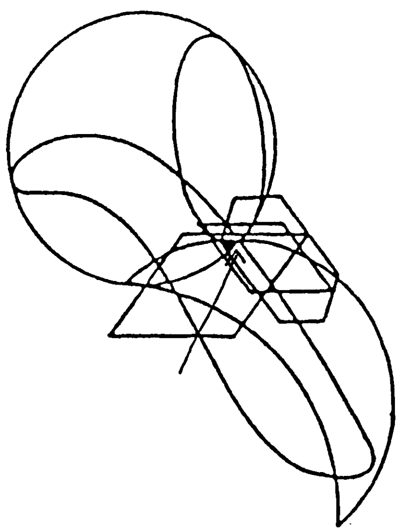


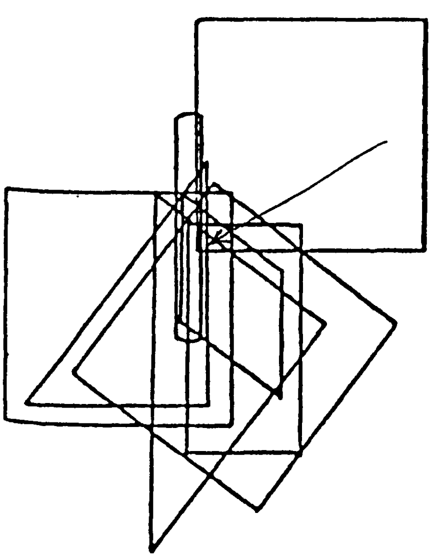








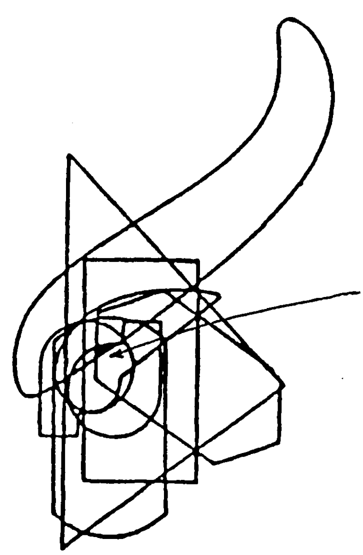


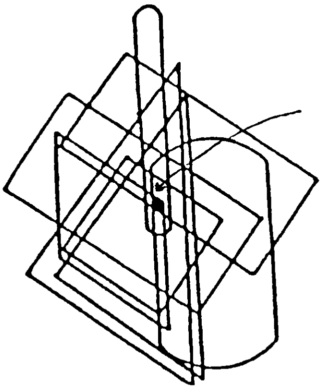
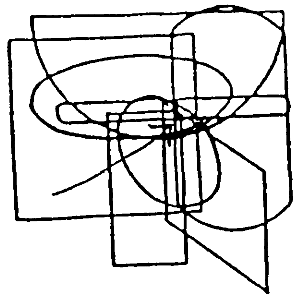
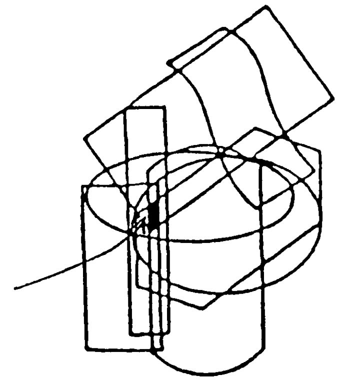
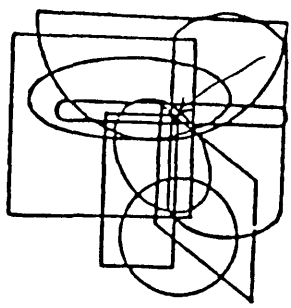
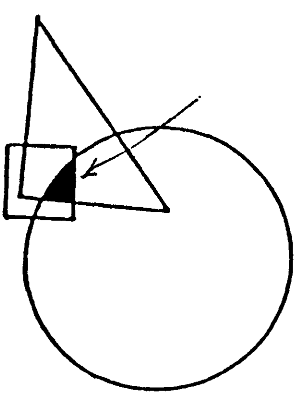
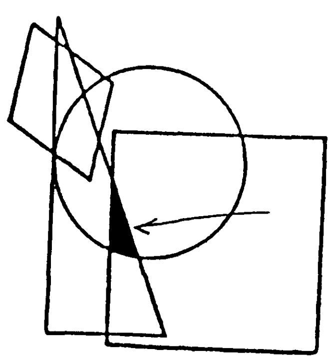
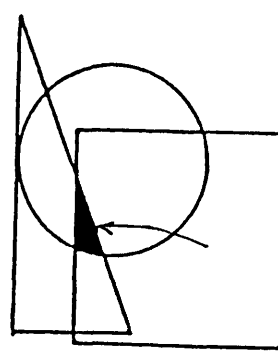
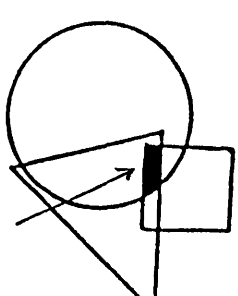
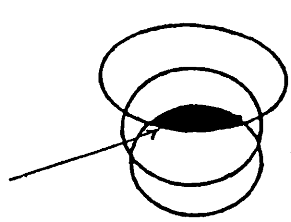










Appendix 3

The analysis of the chemistry questions of the January examination

(first year university biology students)

Question 1

(a) Using the bond energies below, calculate the enthalpy change for the reaction

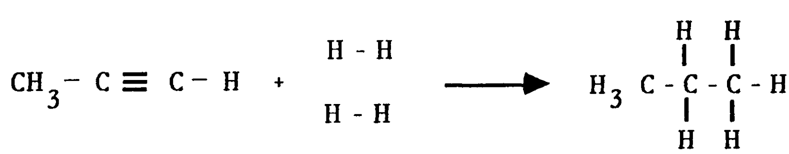
$$CH_3C \equiv CH + 2H_2\ (g) \longrightarrow CH_3\ CH_2\ CH_3\ (g)$$

Propyne   Propane

C – C	348 kJ mol^{-1}
C ≡ C	837 " "
C – H	412 " "
H – H	436 " "

Steps involved

This question could be analysed into 5 thought steps as seen in Chapter 3



Propyne   Propane

(1) Break the triple bond of propyne and break the bonds of hydrogen.

(2) Make four bonds between C - H, and one between C - C.

(3) Calculate the enthalpy of broken bonds

$(+837) + 2(436) = + 1709$ kJ mol^{-1}

(4) Calculate the enthalpy of formed bonds

$(348) - 4(412) = 1996$ kJ mol^{-1}

Appendix 3 (cont'd)

(5) Calculate the enthalpy differences by applying the following equation:

ΔH = total formed bonds + total broken bonds

= (1709) - (1996) kJ mol^{-1}

= - 287 kJ mol^{-1}

(b) If the standard enthalpy of formation of propyne is 183 kJ^{-1} calculate the standard enthalpy of formation of propane.

Steps involved

(6) Recognise the required equation

$\Delta H_f^o = H_f^o$ (products) - H_f^o (reactants)

(7) Recognise which chemical is the reactant and which is the product

(propyne = reactant; propane = product)

ΔH_f^o = - 287 kJ and H_f^o (reactant) = + 183 kJ (from the question).

(8) Rearrange the equation and solve by substitution

H_f^o (propane) = ΔH_f^o + H_f^o (reactant)

= (- 287 + 183) kJ

= - 104 kJ

From the above, the Z-demand for the 1(b) question seems to be 3. But the student needs to solve the 1(a) question and find the result to use it in the 1(b) question therefore the Z-demand of the 1(b) question is equal to 8.

Z = 8

Appendix 3 (cont'd)

Question 2

The temperature dependence of the rate constant for the reaction:

$$CO\,(g) + NO_2\,(g) \longrightarrow CO_2\,(g) + NO\,(g)$$

is tabulated below.

Temperature (K)	600	650	700	750	800
k ($mol^{-1}\ l\ s^{-1}$)	0.028	0.22	1.3	6.0	23

Calculate E_a and k at 400K. [$R = 8.314\ J\ mol^{-1}\ K^{-1}$].

Steps involved

(1) Recall equation

$[\log k_1/k_2 = E_a/2.303\,R\ (1/T_1 - 1/T_2)]$

(2) Modify equation

$[\ln k_1/k_2 = E_a/R\ (1/T_1 - 1/T_2)]$

thereafter replace 'log' with 'ln' and omit '2.303'

(3) Choose adequate results (extremes of data)

(4) Rearrange the equation

$E_a = \log k_1/k_2 \times 2.303 \times R\ /(1/T_1 - 1/T_2)$

(5) Remember

$\log k_1/k_2 = \log k_1 - \log k_2$

(6) Calculate the value of $\log k_1$, $\log k_2$

$\log (k_1/k_2)$

(7) Calculate the value of $1/T_1$, $1/T_2$

$1/T_1 - 1/T_2$

(8) Substitute values

$E_a = 2.918 \times 2.303 \times 8.314\ /0.41$

(9) E_a = 136.13 kJ mol^{-1}

Z = 9

<u>Question 3</u>

A colourless liquid was found to have the composition 60% chlorine, 27% sulphur and 13% oxygen, and to have a molecular weight of about 120 g mol^{-1}. Determine the molecular formula of the compound.

1.02 g of the liquid were allowed to react with water. A vigorous reaction occurred, and care was taken not to allow any gaseous products, one of which was believed to be sulphur dioxide, to escape. Further water was added to make 100.0 ml of solution. 25.0 ml of this solution were acidified with sulphuric acid and titrated with a 0.036 M solution of dichromate ion ($Cr_2O_7{}^{2-}$). 19.7 ml were required to reach an equivalence point. The $Cr_2O_7^{2-}$ ions were reduced to Cr^{3+}.

Write a balanced redox equation for the reaction which had occurred during the titration, determine the amount of sulphur dioxide in solution and hence write an equation for the reaction of the original liquid with water.

[Molecular weight: Cl = 35.3, S = 32.0, O = 16.0]

Steps involved

(1) Recognise that the weight ratio is equal to the composition given in the question

Cl : S : O

60 27 13

(2) Calculate the mole ratio

60 / 35.5 : 27 / 32 : 13 / 16

Appendix 3 (cont'd)

= 1.69 : 0.84 : 0.81

= 2 : 1 : 1

(3) Calculate the molecular weight for the empirical formula

$SOCl_2$

(4) Compare with the molecular weight of the compound (120 g mol^{-1})

formula weight = 119 which agrees approximately with 120 given in the question. Therefore the molecular formula is $SOCl_2$.

(5) Write the reaction of the $Cr_2O_7^{2-}$ with the acid

$Cr_2O_7^{2-}$ + 14 H^+ + 6 e $\longrightarrow$ SO_4^{2-} + 4 H^+ + 2 e .... (A)

(6) Write the reaction of SO_2 with the water

SO_2 + 2 H_2O $\longrightarrow$ SO_4^{2-} + 4 H^+ + 2 e .... (B)

(7) Balance the redox equation for the reaction of dichromate, acid, and sulphur dioxide [by multiplying (B) by 3 and adding to (A)].

$Cr_2O_7^{2-}$ + 2 H^+ + 3 SO_2 $\longrightarrow$ 2 Cr^{3+} + H_2O + 3 SO_4^{2-} .... (C)

(8) Titrate the SO_2 which is the unknown substance with the standard solution of $Cr_2O_7^{2-}$.

(9) Find out the chemical equivalence from the (C) equation

which is $Cr_2O_7^{2-} \equiv 3\ SO_2$

(10) Calculate the number of the moles for the dichromate involved in the titration.

1907/ 1000 (l) $Cr_2O_7^{2-}$ (solution) $\times$ 0.036 mol / 1 (l) = 7.092 $\times$ 10^{-4} mole.

(11) Use the equivalence given in the step (9) to calculate the number of moles for SO_2.

7.092 $\times$ 10^{-4} $\times$ mole 3 (mol) SO_2 / 1 (mol) $Cr_2O_7^{2-}$ $\times$ 100 (mol)/ 25 (mol)

Appendix 3 (cont'd)

= 8.51 m mol SO_2

(12) Calculate the number of moles for the 1.02 g of $SOCl_2$.

1.02 g of $SOCl_2$ = 1.02 / 119 = 8.5 m mol.

(13) Write the equation of the reaction between $SOCl_2$ with the water.

$$SOCl_2 + H_2O \longrightarrow SO_2 + 2\,HCl$$

(14) Calculate the number of the moles of SO_2

$$1\ (mol)\ SOCl_2 \longrightarrow 1\ (mol)\ SO_2$$

Therefore all SO_2 is produced by $SOCl_2$.

Z = 14

Appendix 4

* Derivation of a formula for the maximum width of a confidence interval

The 95% confidence interval about the difference between two proportions is approximately

$$(p_1 - p_2) \pm 1.96 \sqrt{p(1 - p)(1/N_1 + 1/N_2)},$$

(where p_1, p_2, are the proportions in the samples of size N_1, N_2),

and $p = N_1 p_1 + N_2 p_2 / N_1 + N_2$ is the mean proportions.

The width of the confidence interval, W, is given by the second term in the above expression;

$$W = 1.96 \sqrt{p(1 - p)(1/N_1 + 1/N_2)}.$$

The confidence interval will not capture 0 if

$$|p_1 - p_2| > W$$

Although W depends on the values of p_1 and p_2, as well as on the sample sizes, it has a maximum values for any fixed N_1 and N_2, that depends only on the sample sizes.

For fixed N_1 and N_2,

$$W = C \sqrt{p(1 - p)} \qquad C = 1.96 \sqrt{(1/N_1 + 1/N_2)}$$

$$dW/dp = 1/2\, C\, (1 - 2p) / \sqrt{p(1 - p)}$$

$$= 0 \text{ when } p = 1/2.$$

When $p = 1/2$, W takes on its maximum value,

$$W_{max} = 1.96 / 2 \sqrt{(1/N_1 + 1/N_2)}$$

Let $x = N_1/N_2$

then $W_{max} = 1.96 / {}^2\sqrt{N_2} \sqrt{1 + 1/x}.$

In the general case, it is convenient to define a new variable,

$$W = 1.96 / 2 \sqrt{1} + 1/x.$$

Appendix 4 (cont'd)

Values of W may be recorded (by tabulation or graphically) for

$.01 > x > 1.$

If $|p_1 - p_2| > W_{max}$'

i. e. $> W / \sqrt{N_2}$

then the confidence interval about $(p_1 - p_2)$ will not capture 0, whatever the values of p_1 and p_2.

If percentages rather than proportions are used, the required differences is $100w / \sqrt{N_2}$.

If you have two samples:

1. Designate the smaller N_1 and the larger N_2.
2. Calculate N_1 / N_2 = value on x axis
3. From graph read off Δ
4. The $\Delta / \sqrt{N_1}$

   % $(p_1 - p_2)$ which must be significant

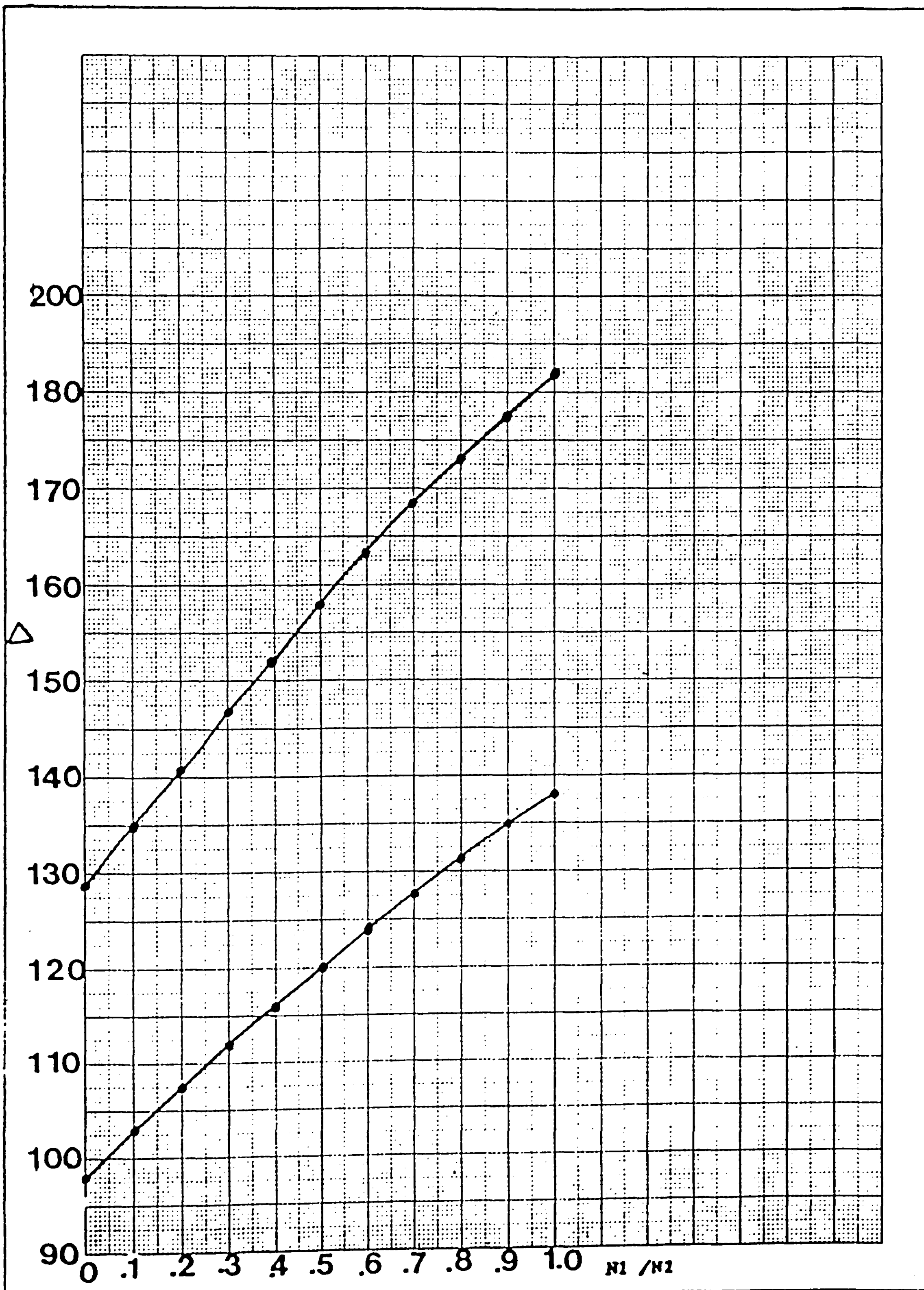
   independent of p_1 and p_2.
5. If ratio x $\sim$.1 or .9 then

   $0.6 \times \Delta / \sqrt{N_2}$ will still be significant.
6. If ratio x $\sim$.2 or .8 then

   $0.8 \times \Delta / \sqrt{N_1}$ will still be significant.
7. If ratio x $\sim$.3 or .7 then 0.9 x will still be sig.

   x $\sim$.4 or .6 then 0.98 x will still be sig.

   x $\sim$.5 or .95 then 0.43 x will still be sig.



* Extracted from reference No. [46].

Appendix 5

The analysis of the chemistry questions of the April examination (first year university biology students)

Question 1

What concentration of NH_4Cl must be presented in a 0.20 M solution of NH_3 to adjust the pH to 10.0 (pKb for NH_3 = 4.74 at 25^oC).

Z = 8

Question 2

Find the pH and degree of dissociation a for a 5×10^{-3} M solution of ethanoic acid (Ka = 1.8×10^{-3} at 25^oC).

Z = 6

Question 3

This question refers to the grid provided. In most parts of the question the answer required is a number, or a set of numbers, corresponding to the box numbers in the grid.

For example: Select the boxes containing nickel complexes. The answer would be 2, 5, 9.

(a) Select a box (or boxes) which contain(s) a complex in the "fac" form.

Z = 2

(b) What is the oxidation state of the metal ion shown in box 7?

Z = 4

Appendix 5 (cont'd)

(c) Give the electronic configuration for the metal ion in box 7.

Z = 5

(d) Which boxes contain complexes which form a pair of chiral isomers?

Z = 5

(e) If the complex in box 3 is paramagnetic (with two unpaired electrons), which other box(es) contain(s) complexes which you can be <u>sure</u> will be <u>more</u> paramagnetic?

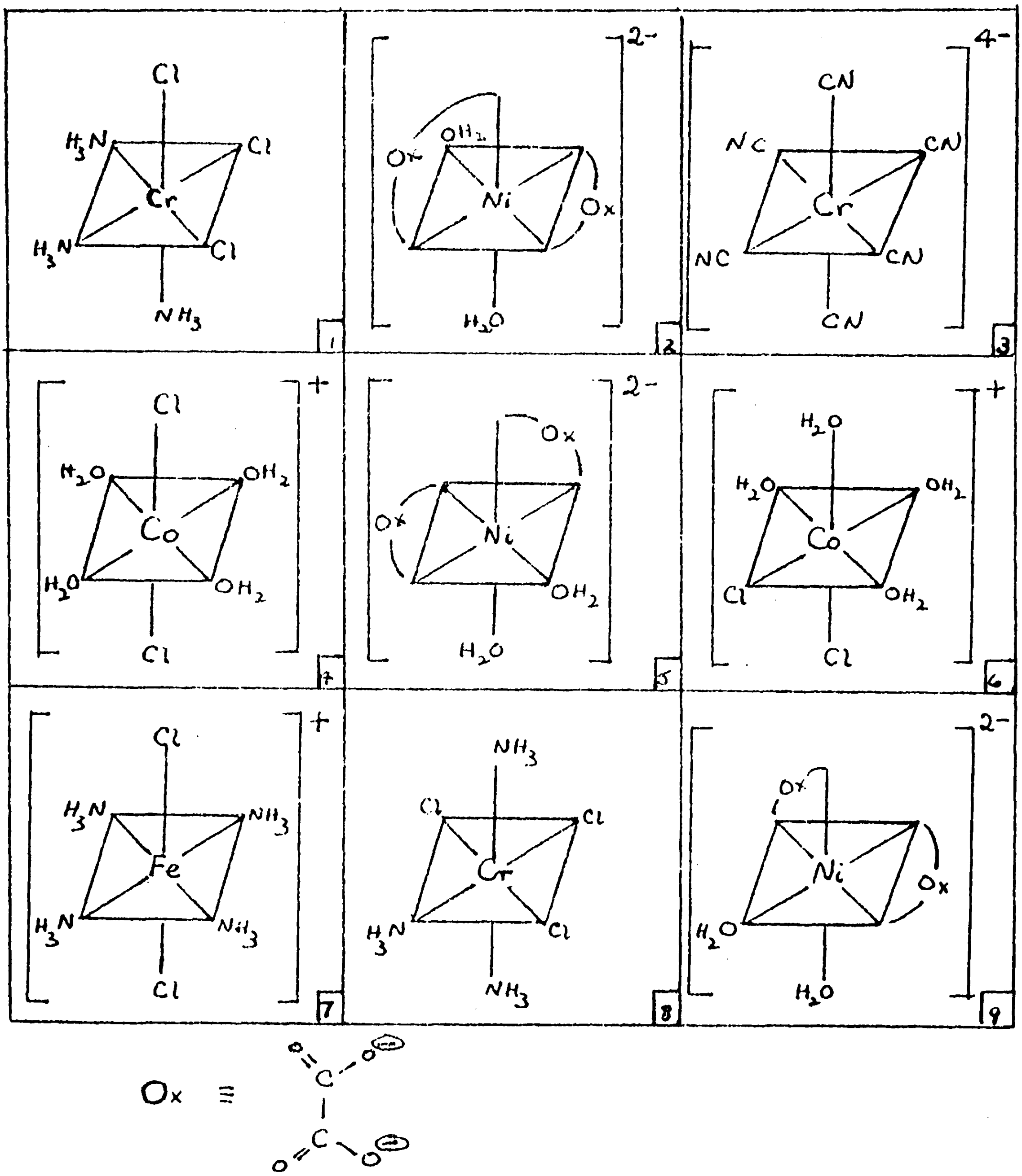
Z = 7

(f) Which other boxes contain complexes which are <u>likely</u> to be <u>more</u> paramagnetic?

Write a sentence or two to explain your choices in (e) and (f).

Z = 8

The grid is to be shown in the <u>next page</u>.



Cl
H3N
Cl
Cr
H3N
Cl
NH3
1
2-
Ox
OH2
Ni
Ox
H2O
2
4-
CN
NC
CN
Cr
NC
CN
CN
3
+
Cl
H2O
OH2
Co
H2O
OH2
Cl
4
2-
Ox
Ox
Ni
OH2
H2O
5
+
H2O
H2O
OH2
Co
Cl
OH2
Cl
6
+
Cl
H3N
NH3
Fe
H3N
NH3
Cl
7
NH3
Cl
Cl
Cr
H3N
Cl
NH3
8
2-
Ox
Ni
Ox
H2O
H2O
9
Ox ≡

Appendix 6

The analysis of the chemistry questions of the June examination (first year university biology students)

<u>Question 1</u>

In a complex of cobalt, analysis has shown that there are ammonia molecules, water molecules and chloride ions associated with the metal ion.

(a) If the formula of the complex was $[Co(NH_3)_4(H_2O)Cl]Cl_2$,

(i) name it,

Z = 4

(ii) calculate the number of d electrons on the cobalt ion,

Z = 3

(iii) draw the possible isomers of the complex ion

(i. e. the part in square brackets).

Z = 2

(b) During the analysis, 2.52 g of the complex were treated with an excess of silver nitrate solution. The precipitate of silver chloride was filtered, dried and weighed. its mass was 2.87 g.

Show by calculation if these results are consistent with the formula we have assumed above.

[relative Atomic Masses: Co = 59; N = 14; H = 1; O = 16; Cl = 35.5; Ag = 108]

Z = 6

Question 2

A solution of 6.85 g of $X(OH)_2$ dissolved in 500 ml of water was found to have an osmotic pressure of 5.88 atm at 25^oC. Assuming complete dissociation of $X(OH)_2$, calculate the atomic weight of X. (R = 0.0821 l atm K^{-1} mol^{-1}; Atomic weight: O = 16.0, H = 1.01)

Z = 6

Question 3

In an attempt to clear a snow-covered airport runway it was sprayed with a brine solution containing 10 g of NaCl per litre of water. If the air temperature was -5^oC would this measure succeed?

(For water k_f = 103.2 K; Atomic weights: Na = 23.0, Cl = 35.5)

Z = 5

Question 4

Natural potassium contains a radioactive isotope ^{40}K which is present to the extent of 0.0118% and has a half life of 1.27×10^9 y.

Calculate the activity, in becquerels, of 1.000 g of potassium sulphate and give your answer to the correct number of significant figures.

Data needed:

[Atomic weights: K = 39.1; S = 32; O = 16.0.

Avogadro's Constant = 6.02205×10^{23} mol^{-1}; ln 2 = 0.69315.]

Z = 9

Appendix 6 (cont'd)

Question 5

A galvanic cell is constructed in which the overall reaction is:

$Pb\,(s) \quad + \quad 2H^{+}\,(aq) \quad \rightarrow \quad Pb^{2+}\,(aq) \quad + \quad H_2\,(g)$

(a) Calculate ΔG^{o} for the overall cell reaction, stating the units clearly.

Z = 3

(b) Using the value for ΔG^{o} from above, calculate the equilibrium constant K for the overall cell reaction at $25^{o}C$.

[Standard reduction potential for Pb^{2+} (aq) is;

$Pb^{2+}\,(aq) + 2\,e \rightleftharpoons Pb\,(s);\qquad E^{o} = -0.126$

F = 96,500 C

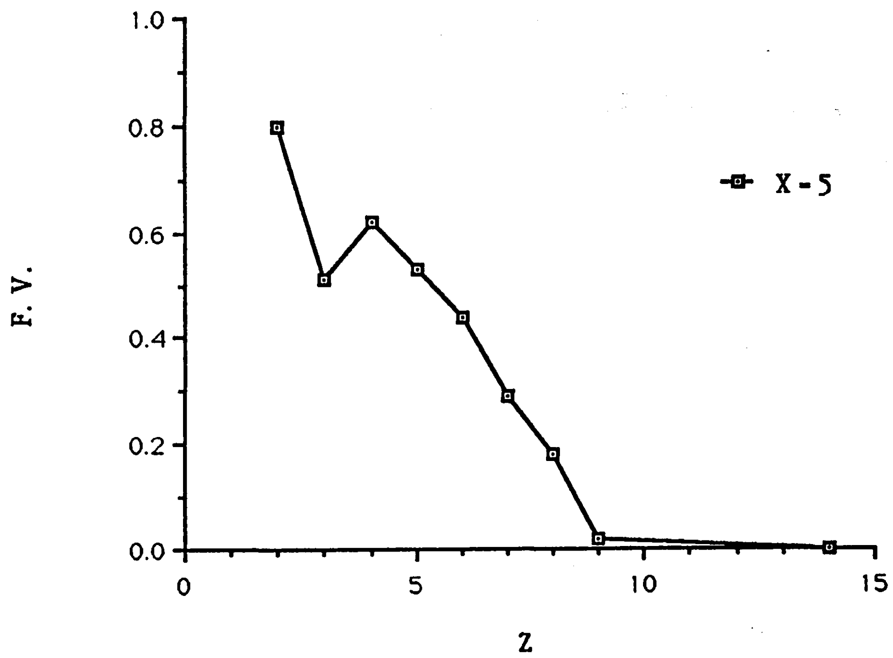
R = 8.314 J K^{-1} mol^{-1}

$0^{o}C$ = 273 K]

Z = 4

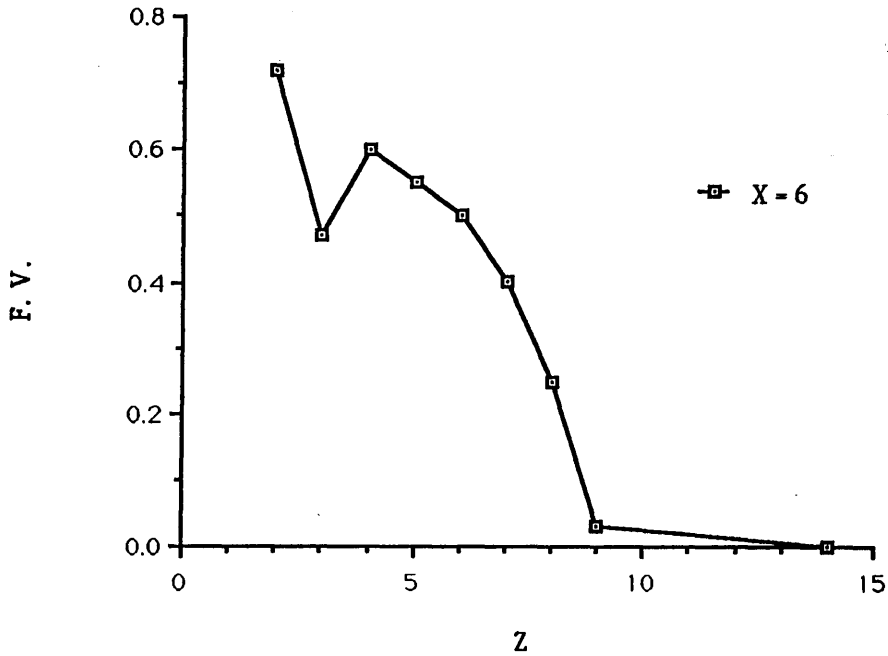
Appendix 7

The performance of the students' groups (first year university biology students) separately in the January and April chemistry examination (a combination)

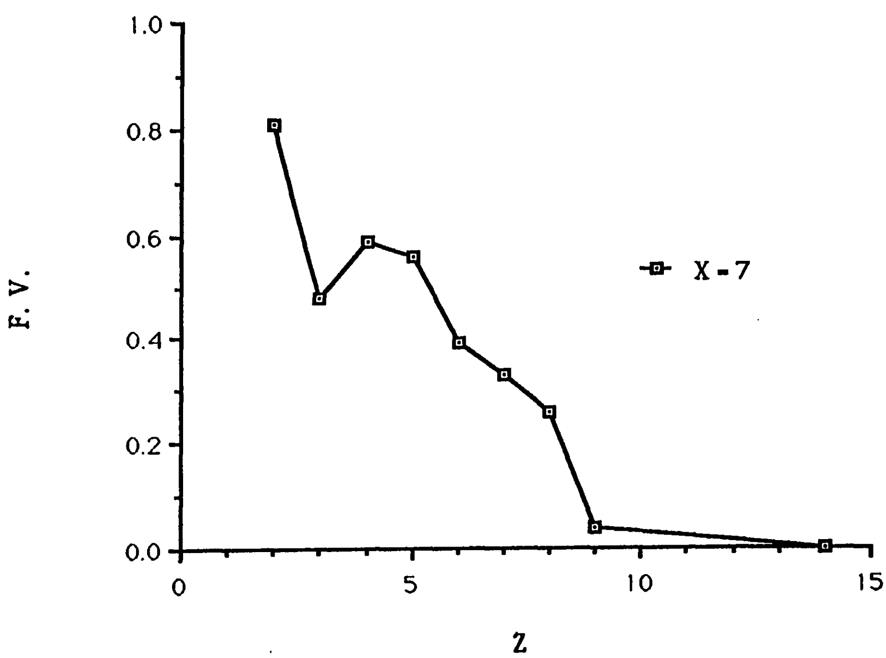


(a) The performance of the X=5 students in the chemistry examinations.

Appendix 7 (cont'd)



(b) The performance of the X=6 students in the chemistry examinations.



(c) The performance of the X=7 students in the chemistry examinations.

Appendix 8

LETTER SPAN TEST

NAME: MALE/FEMALE

MATRIC. NUMBER: DATE OF BIRTH:

PRACTICE ITEMS

4					
5					

TEST ITEMS

2								
3								
4								
5								
6								
7								
8								

Appendix 9

The analysis of the chemistry questions of the January examination (first year university chemistry students)

Question (1)

For the reaction

$$2NO + O_2 \rightarrow 2NO_2$$

at 300 K, the initial rate of consumption of oxygen at various initial reactant concentrations is as follows.

	Initial [NO] (mol l^{-1})	Initial [O_2] (mol l^{-1})	Initial rate of consumption of O_2 (mol l^{-1} s^{-1})
Expt. 1	0.010	0.010	0.00120
2	0.005	0.020	0.00060
3	0.005	0.005	0.00015
4	0.010	0.020	0.00240

(i) Deduce the orders of reaction with respect to NO and O_2, showing how you have obtained them.

Z = 4

(ii) Calculate the value of the rate constant at 300 K, giving its units.

Z = 6

(iii) The reaction is believed to take place by a two-step mechanism:

Either (1) $NO + O_2 \rightleftharpoons NO_3$ (fast equilibrium)

(2) $NO + NO_3 \rightarrow 2NO_2$ (slow)

Or (1') $NO + NO \rightleftharpoons N_2O_2$ (fast equilibrium)

(2') $N_2O_2 + O_2 \rightarrow 2NO_2$ (slow)

Describe very briefly what is meant by the term 'RATE-DETERMINING STEP' and use this principle to obtain the rate expression for each of the mechanisms given above. Can you choose between them in view of your answers in (i)?

Z = 9

Question (2)

(a) Use the VSEPR rules to draw the shapes of BF_3, PF_3, and ClF_3.

(Hint - they all have different shapes).

Z = 6

(b) For each molecule work out whether it has a net dipole and, if it has, show the direction of the dipole.

Z = 2

The student, to solve the question (2b), needs to solve the question (2a) firstly. Therefore, this question (a, and b) was considered as a one question of

Z = 8

Appendix 9 (cont'd)

Question (3)

(a) From the data given below, calculate ΔH^o and ΔS^o for the reaction

$$Cl_2\ (g) \quad + \ 2NO\ (g) \longrightarrow 2NOCl_2\ (g).$$

Calculate ΔG^o for the reaction at temperatures of 300 K and 800 K and deduce which of these temperatures would be preferred choice for the preparation of NOCl.

	$\Delta H^o{}_f$ (kJ mol^{-1})	S^o (JK^{-1} mol^{-1})
NOCl (g)	51.7	261.6
NO (g)	90.3	210.7
Cl_2 (g)		223.0

Z = 7

(b) Deduce the <u>sign</u> of ΔH^o and the <u>sign</u> of ΔS^o for the reaction

$$N_2O_2\ (g) \longrightarrow 2NO_2\ (g)$$

Give clear explanations in each case.

Z = 5

Question (4)

(a)

(i) Calculate the frequency of the n = 5 to n = 2 electron transition in the hydrogen atom ($R_H = \ 2.18 \times 10^{18}$ J, $h = 6.63 \times 10^{-34}$ Js).

Z = 3

(ii) To which spectral series does the line of this frequency belong?

Z = 1

Appendix 9 (cont'd)

The student, to solve the question (ii), needs to solve the question (i) firstly. Therefore, this question (i, and ii) was considered as a one question of

$Z = 4$

(i i i) What is the ionisation energy of the hydrogen atom?

$Z = 7$

(b)

(i) Write down the electronic configuration of the atom with atomic number 34.

$Z = 1$

(i i) How many electron spins has this atom.

$Z = 2$

(i i i) To which group of the periodic table does element number 34 belong?

$Z = 2$

The whole (b) question was considered as a one question of

$Z = 8$

Appendix 10

The analysis of the chemistry questions of the April examination (first year university chemistry students)

Question (1)

Polystyrene has a glass transition temperature (T_g) of 100^oC.

(a) Describe the physical state of the polymer at 20^oC and at 120^oC.

Z = 3

(b) Indicate two properties of polystyrene which are useful in applications of the polymer and three properties which limit its usefulness.

Z = 5

(c) A polystyrene sample has a number average molecular weight (M_n) of 100,000. If the osmotic pressure of a solution containing 5.00 g of the polymer per litre is 1.825×10^{-3} atm at 25^oC, predict (graphically or otherwise) the osmotic pressure of a solution containing 10.00 g of the polymer per litre, making clear your reasoning. (The Gas Constant, R = 0.08205 litre atm deg^{-1} mol^{-1}.)

Z = 9

Question (2)

The crystal structure of metallic iron is

(i) body-centred cubic below 910^oC, and

(ii) cubic close packed (face centred cubic) above 910^oC.

The density of the body-centred cubic form is 7.45 g cm^{-3} at $910^{o}C$. Draw a diagram of the cubic closed packed (face centred cubic) unit cell and determine the number of iron atoms in it. If the radius of the iron atom at $910^{o}C$ is 1.26 A^{o}, calculate the volume of this unit cell and hence the percentage change in the density when the transition takes place at $910^{o}C$. Which structure has the higher density?

[$1A^{o} = 10^{-8}$ cm; Atomic weight of Fe = 55.9 g mol^{-1};
Avogadro's Constant = 6.02×10^{23} mol^{-1}.]

Z = 8

Question (3)

50 ml of 0.1M ethanoic acid is titrated against 0.1M NaOH. Calculate the pH after 49.9 ml of NaOH has been added to the acid [K_a (ethanoic acid) = 1.85×10^{-5}].

Z = 8

Question (4)

This question refers to the grid provided (next page). In most parts of the question the answer required is a number, or a set of numbers, corresponding to the box numbers in the grid.

For example: Select the boxes containing cobalt complexes.

The answer would be 1, 3, 7, 9.

(a) Which box contains fac-trichlorotriammine chromium (III)?

Z = 2

(b) Which two boxes contain a pair of geometric isomers of cobalt?

Z = 4

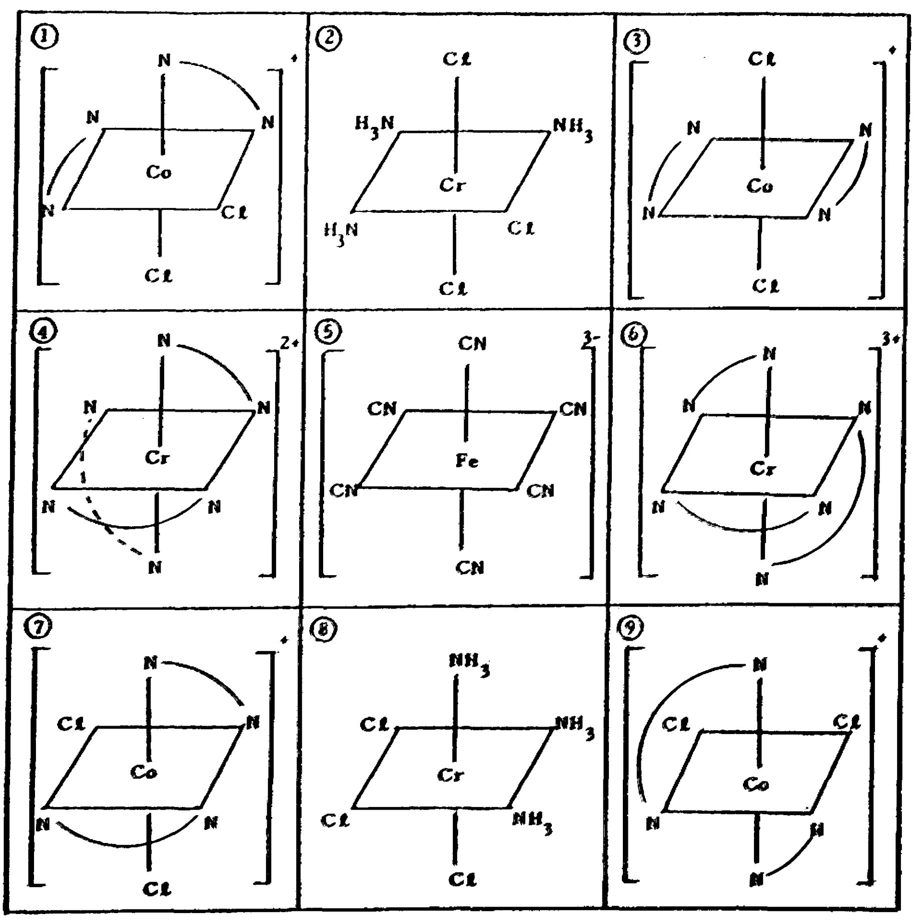
Appendix 10 (cont'd)

(c) Which box contains a complex the metal ion of which is in a different oxidation state from the metals in all of the other complexes?

Z = 4

(d) Which box(es) contain complex(es) of which the metal ion has a d^3 configuration?

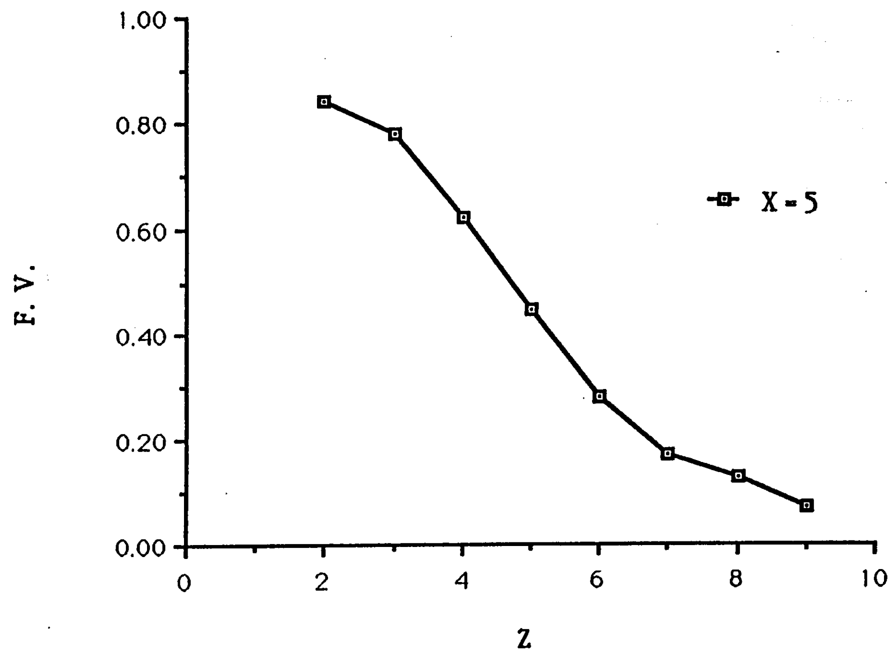
Z = 6



N⌒N = 1,2-diaminoethane (or en)

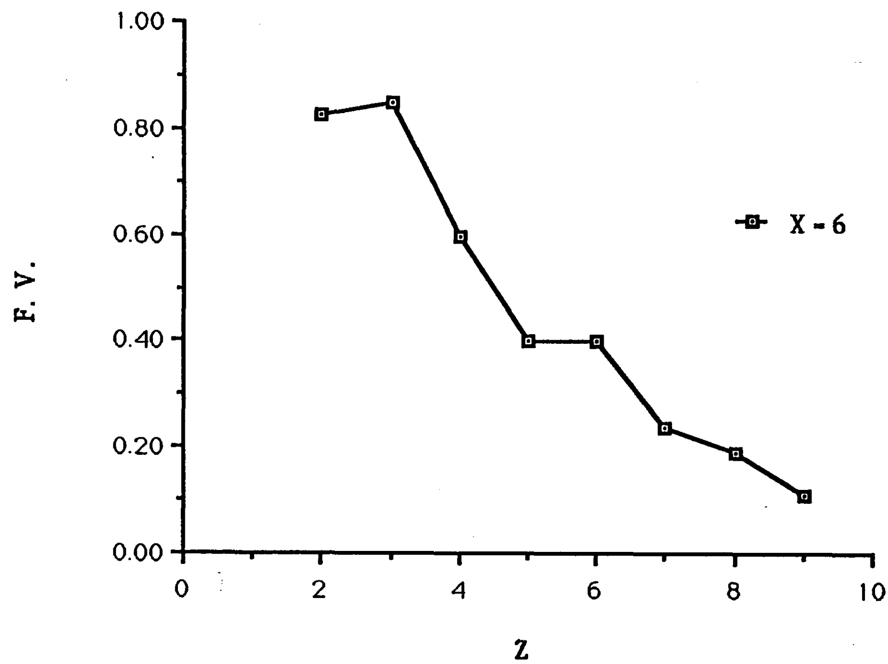
Appendix 11

The performance of the students' groups (first year university chemistry students) separately in the January and April chemistry examination (a combination)

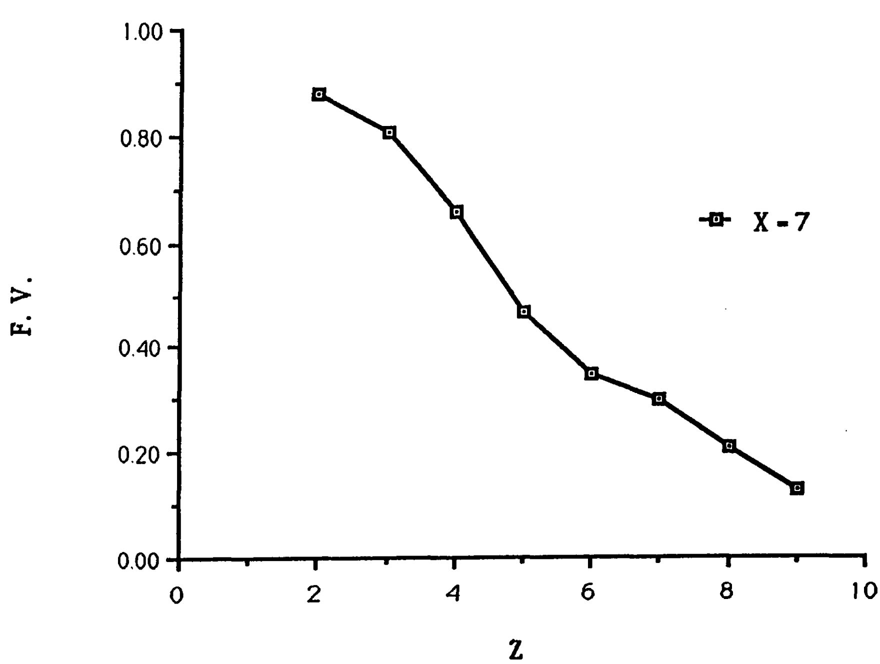


(a) The performance of the X=5 students in the chemistry examinations.

Appendix 11 (cont'd)



(b) The performance of the X=6 students in the chemistry examinations.



(c) The performance of the X=7 students in the chemistry examinations.

Appendix 12

The analysis of the chemistry examination questions of the Hucheson's Grammar School ("O" Grade pupils)

Question (1)

Ion	No. of electrons
$^{7}_{3}Li^{+}$	2
$^{27}_{13}X^{+3}$	a
$^{32}_{16}Y^{-2}$	b

On your answer sheet write

(a) X and Y and give the chemical symbol for each.

Z = 2

(b) a and b and give the number of electrons for each.

Z = 4

Question (2)

Ammonium nitrate, NH_4NO_3 is a useful fertilizer. Calculate the mass of nitrogen in 100 kg of the fertilizer.

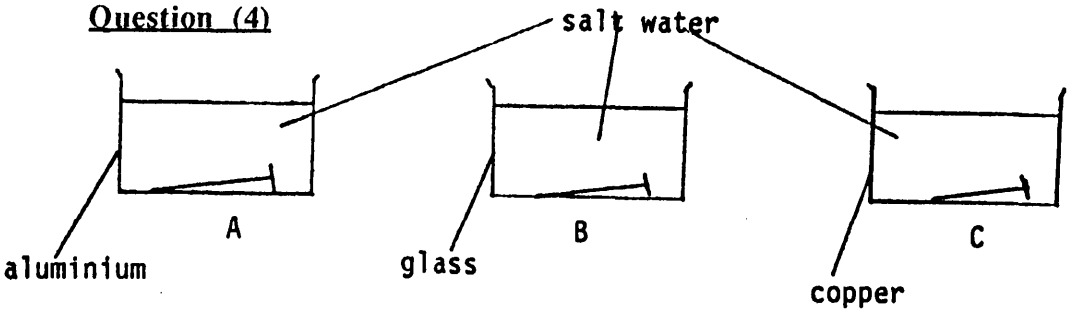
Z = 5

Question (3)

A compound is 31.4% boron and 68.6% oxygen. Calculate the empirical formula of the compound.

Z = 5

Question (4)



An iron nail lies on the bottom of each beaker.

(a) The iron nail in beaker B became rusty in a few days. What caused the iron to rust?

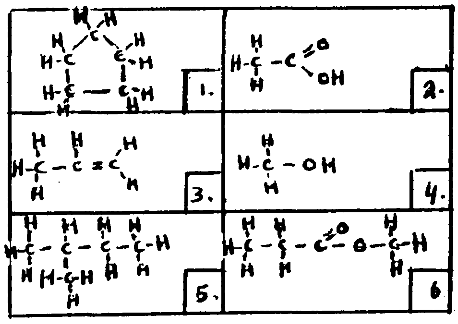
Z = 3

(b) In which beaker would most rust appear? Give a reason for your answer.

Z = 5

Question (5)

Consider the organic compound represented by the formula shown in the grid.



Appendix 12 (cont'd)

Answer the following questions by giving grid number(s)

(a) Which compound could be used to form an addition polymer?

Z = 5

(b) Which compound could be formed by hydrolysis of the compound represented by 6 ?

Z = 5

(c) Which compound is an (i) alkanoic acid? (ii) an alkanol?

Z = 4

(d) Which compound is an ester?

Z = 3

(e) Which compound is unsaturated?

Z = 3

Appendix 13

The analysis of the chemistry examination questions of the Graeme High School ("O" Grade pupils)

<u>Question (1)</u>

Consider a list of elements:_ Lithium, calcium, silicon, bromine, oxygen, argon.

(a) Which element has 35 electrons in each of its atoms?

Z = 2

<u>Question (2)</u>

Use of a mass spectrometer shows that silver has two isotopes.

(a) How many neutrons are present in a silver atom with mass number 107?

Z = 5

<u>Question (3)</u>

In an experiment to investigate the rusting of iron, nails were put in test-tubes as shown below, and left for one week.

Tube number	Contents of tube
1	Nail + tap water
2	Nail + salt water
3	Nail attached to zinc + tap water
4	Nail attached to copper + tap water
5	Nail attached to copper + salt water

(a) In which tube was rusting most severe?

Z = 5

(b) In which tube had no rusting taken place?

Z = 5

Question (4)

A magnesium ion containing 12 protons, 12 neutrons and 10 electrons may be represented by the symbol $^{24}_{12}Mg^{2+}$

Show how you would represent

(i) a sulphide ion with 16 protons, 16 neutrons and 18 electrons.

Z = 4

(ii) an aluminium ion with 13 protons, 14 neutrons and 10 electrons.

Z = 4

Question (5)

Refer to the following compounds to answer the questions which follow.

1. CCl_4 (l) 2. CuO (s) 3. CO_2 (g) 4. NaF (s) 5. $CuCl_2$ (s) 6. CH_4 (g)

Appendix 13 (cont'd)

(a) Atoms join together in different ways. Explain how the atoms join together to form a molecule of compound 6. Your explanation should include a description of how the outer electrons of each atom are involved.

Z = 6

(b) Consider compounds 4 and 5. Explain why they do not conduct electricity when solid but do conduct electricity when melted or dissolved in water.

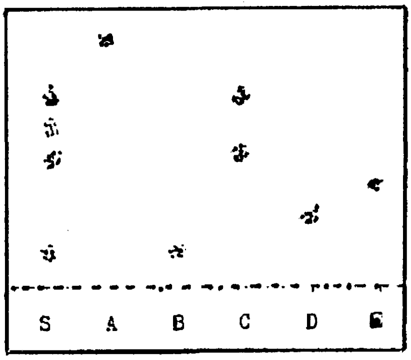
Z = 7

(c) Divide the compounds into two groups headed 'Ionic compounds' and 'Covalent compounds'.

Z = 6

<u>Question (6)</u>

The stomach contents of a drug-overdose victim were analysed by paper chromatography. The results are shown below. Stomach contents are marked 'S'. Known drugs are marked 'A', 'B', 'C', 'D' and 'E'.



Appendix 13 (cont'd)

(a) Which drugs has the patient taken?

Z = 3

(b) Are further tests required? Explain your answer.

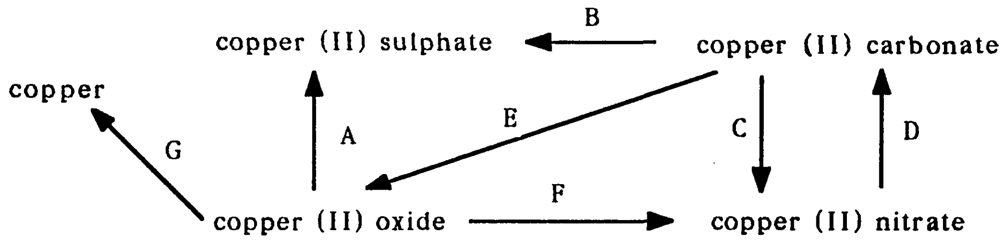
Z = 4

Appendix 14

The analysis of the chemistry examination questions of the Trinity High School ("O" Grade pupils)

Question (1)

The diagram below shows a cycle of chemical changes.



(a) Name a change which can be brought about by heat alone.

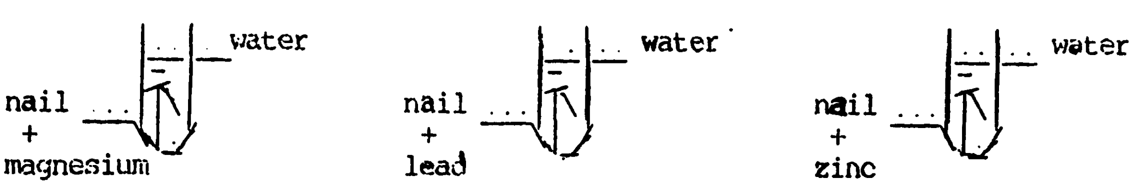
Z = 8

(b) Which substance can bring about change A?

Z = 4

Question (2)

Iron nails are connected to various metals as shown below:



(a) In which tube will rusting occur?

Z = 3

Question (3)

Calculate the volume of 0.5M sodium hydroxide necessary to neutralise 50 cm^3 of 1M hydrochloric acid. (Show your working)

Z = 7

Question (4)

Explain the meaning of each of the following statements; giving examples.

(a) The element carbon has more than one polymorph.

Z = 6

(b) The element carbon has more than one isotope.

Z = 6

Question (5)

A pupil carries out an experiment to investigate the conductivity of three solutions and obtained the following results.

	50 cm^3 of solution	Current (mA)
X	0.1M hydrochloric acid	90
Y	0.1M sodium chloride	62
Z	0.1M ethanoic acid	19

Using these results, explain the difference in readings between:

(a) Solution X and Y

Z = 6

(b) Solution X and Z

Z = 5

Question (6)

YOU ARE NOT EXPECTED TO HAVE ENCOUNTERED CALCIUM HYDRIDE BEFORE.

Calcium hydride is an ionic substance with the ionic formula $Ca^{2+} H_2^-$.

Calcium hydride reacts violently with water producing a colourless gas which burns with a 'pop'.

(a) What is unusual about the charges shown in the ionic formula of calcium hydride?

Z = 3

(b) What might be the gas produced when calcium hydride is added to water?

Z = 2

(c) Suggest a reason why the electrolysis of calcium hydride can be carried out in the molten state but not in aqueous solution.

Z = 5

Appendix 15

The analysis of the chemistry examination questions of the Stirling High School ("O" Grade pupils)

Question (1)

Setting out your working clearly, calculate the percentage by weight of hydrogen in $(NH4)_2S$.

Z = 5

Question (2)

Two white solids are known to be potassium sulphite and potassium sulphate. How could you tell which is which?

Z = 7

Question (3)

The balanced equation for the burning of hydrogen is

$$2H_2 + O_2 \rightarrow 2H_2O$$

(a) In an experiment 36 g of water was produced from 4 g of hydrogen. What weight of oxygen was used up in the reaction?

Z = 2

(b) How many moles of water were produced from 4 g of hydrogen?

Z = 3

Question (4)

What weight of sodium hydroxide (NaOH) is needed to make 250 cm^3 of 0.5M sodium hydroxide solution?

Z = 6

Question (5)

(a) Describe what happens when burning Mg is placed in a gas jar of SO_2.

Z = 6

(b) State whether sulphur dioxide behaves as an oxidising agent or a reducing agent when burning Mg is placed in a gas jar of SO_2.

Z = 4

Question (6)

Consider the gases in the grid

CO_2 1	H_2 2	C_2H_6 3
CO 4	C_2H_4 5	SO_2 6
NH_3 7	O_2 8	N_2 9

Answer the following questions by giving the grid number:

(a) What 2 gases make up 99% of the air?

Z = 4

(b) Which gases would decolourise bromine water?

Z = 8

(c) Which gases would turn moist blue litmus red?

Z = 6

(d) Which gases could reduce copper (II) oxide to copper?

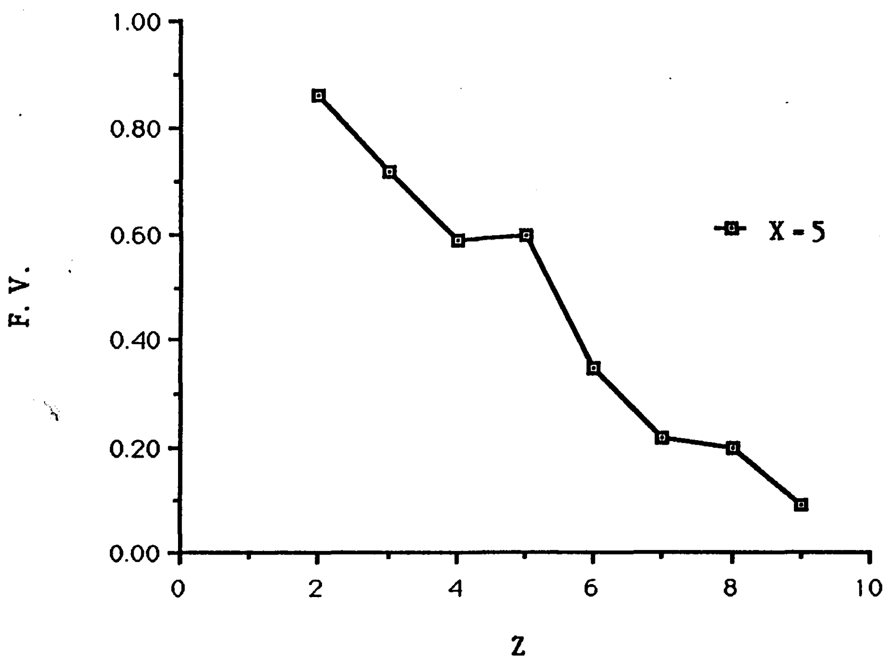
Z = 9

(e) Which gases would burn to give only CO_2?

Z = 5

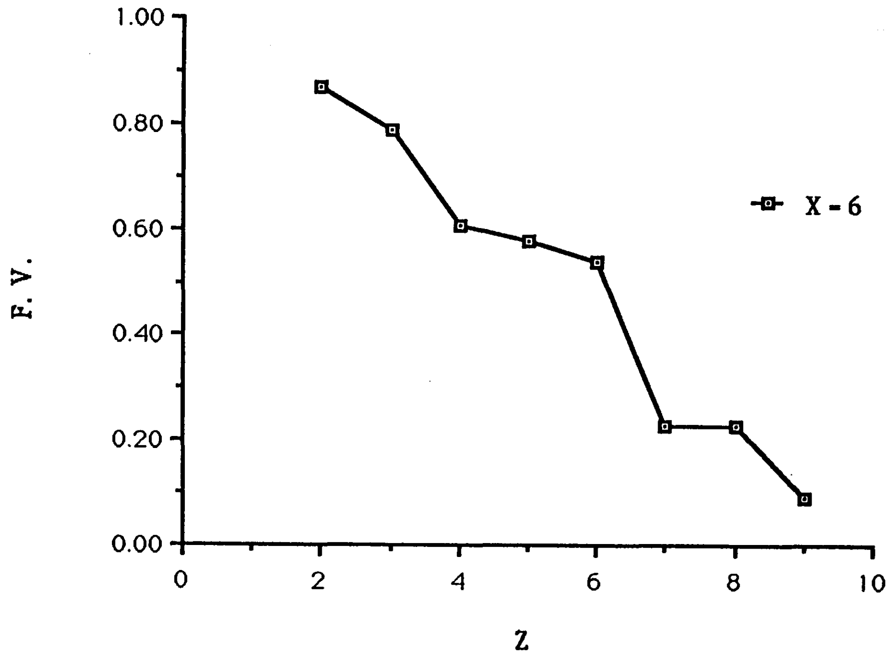
Appendix 16

The performance of the pupils' groups ("O" Grade School Pupils) separately in the chemistry examination (a combination)

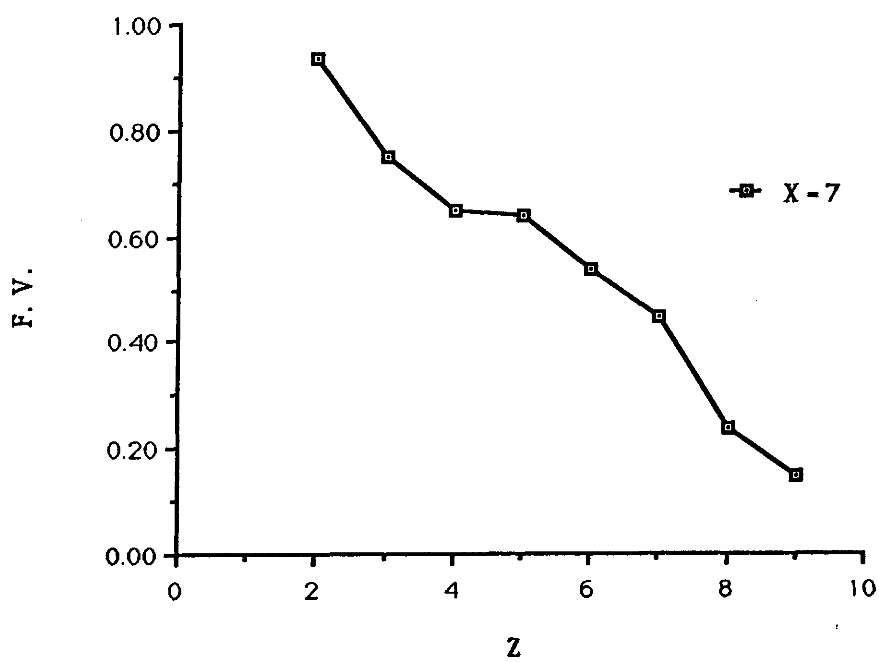


(a) The average performance of the X=5 pupils in the chemistry examination.

Appendix 16 (cont'd)



(b) The average performance of the X=6 pupils in the chemistry examination.



(c) The average performance of the X=7 pupils in the chemistry examination.

Appendix 17 (a)

THE FD/FI TEST (HFT)

NAME: SEX:

SCHOOL: DATE OF BIRTH:

CLASS:

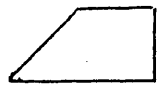
This is a test of your ability to find a simple shape when it is hidden within a complex pattern.

The results will not affect your school work in any way.

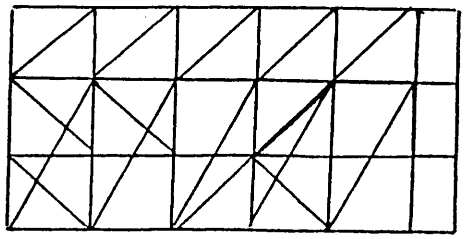
<u>Example (1)</u>

Here is a simple shape which we have labelled (X):

(X)



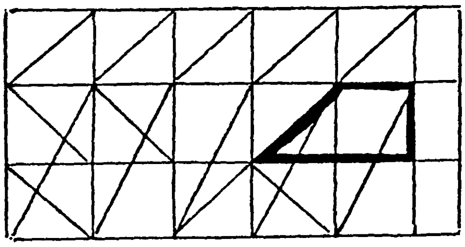
This simple shape is hidden within the more complex figure below:



Try to find the simple shape in the complex figure and trace it in pen directly over the lines of the complex figure. It is <u>the same size</u>, in <u>the same proportions</u>, and <u>faces in the same direction</u> within the complex figure as when it appeared alone.

(When you finish, turn the page to check your answer.)

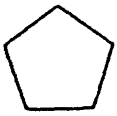
Appendix 17 (a) (cont'd)

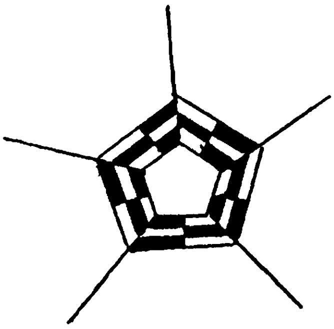


Example (2)

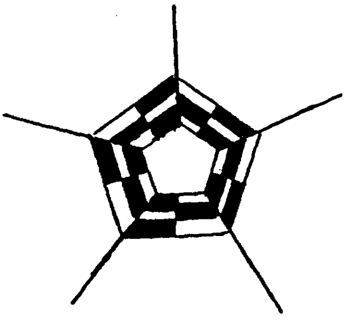
Find and trace the simple shape (Y) in the complex figure beside it.

(Y)





The answer is:



Appendix 17 (a) (cont'd)

In the following pages, problems like the ones above will appear. On each page you will see a complex shape, and beside it will be an indication of the simple shape which is hidden in it. For each problem, try to trace the simple shape in pen over the lines of the complex shape.

Note these points:

(1) Rub out all mistakes.

(2) Do the problems in order. Don't skip a problem unless you are absolutely stuck on it.

(3) Trace only one simple shape in each problem. You may see more than one, but just trace one of them.

(4) The simple shape is always present in the complex figure in the

same size,

same proportions,

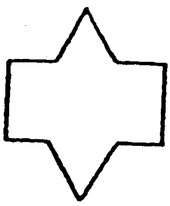
and facing in the same direction;

as it appears alone.

(5) LOOK BACK AT THE SIMPLE FORMS AS OFTEN AS NECESSARY.

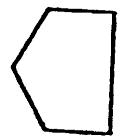
Now: Attempt each of the items on the following sheets.

SIMPLE FORMS

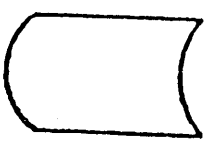


A

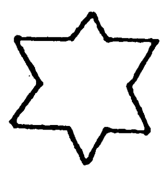
B



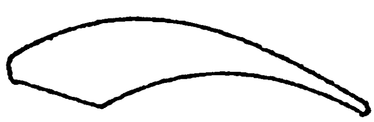
C



D

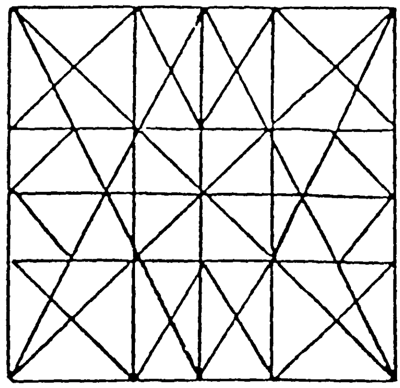


E

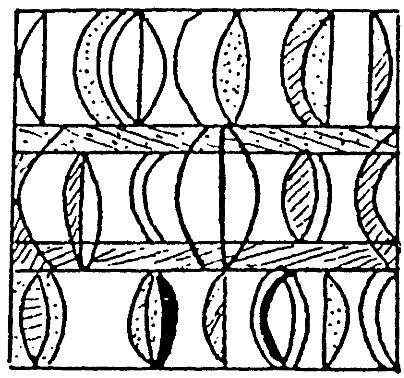


G

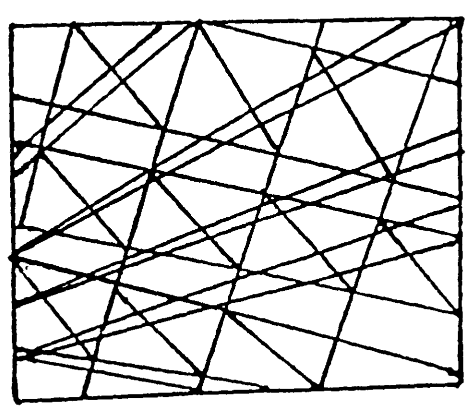
Find Simple Form "C"



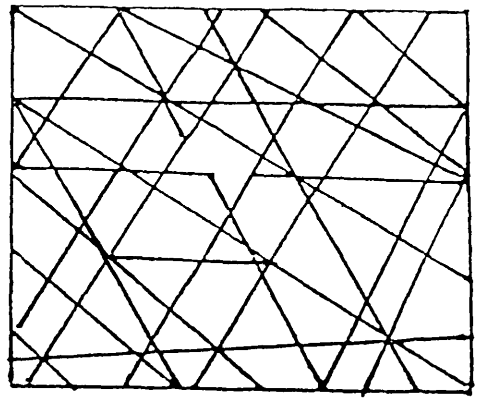
Find Simple Form "D"



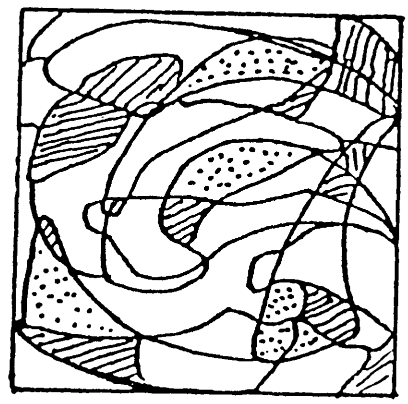
Find Simple Form "B"



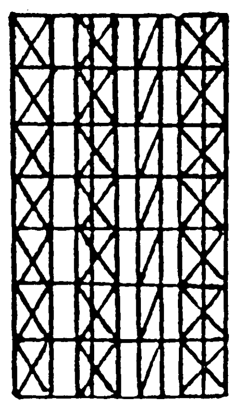
Find Simple Form "E"



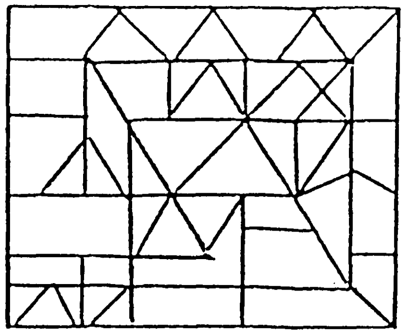
Find Simple Form "G"



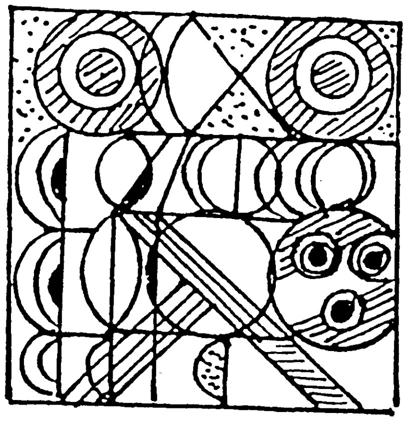
Find Simple Form "C"



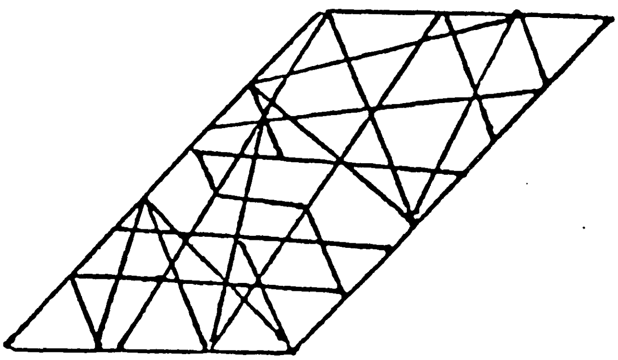
Find Simple Form "A"



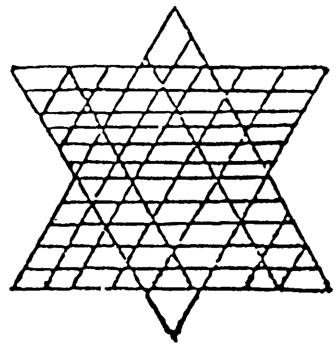
Find Simple Form "D"



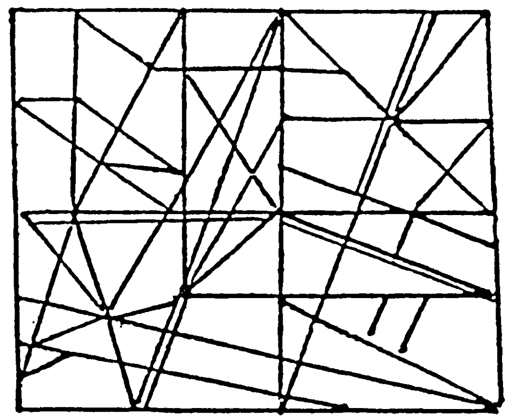
Find Simple Form "E"



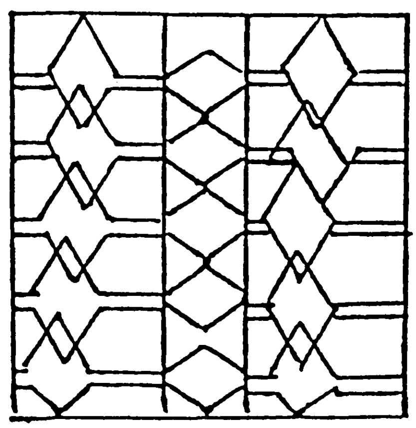
Find Simple Form "E"



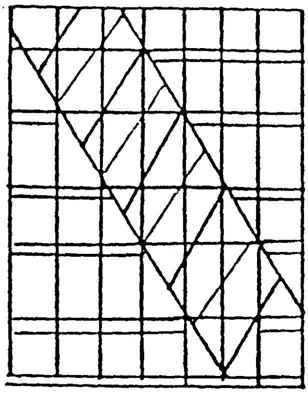
Find Simple Form "B"



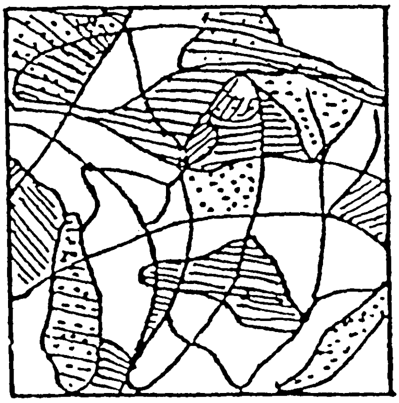
Find Simple Form "A"



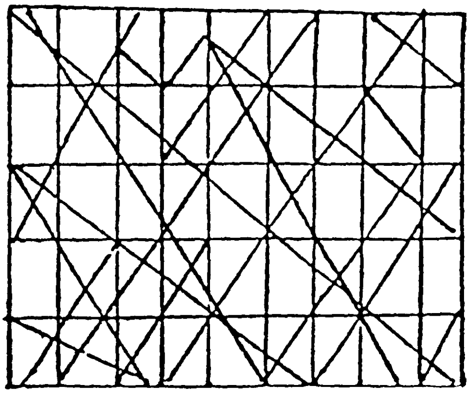
Find Simple Form "A"



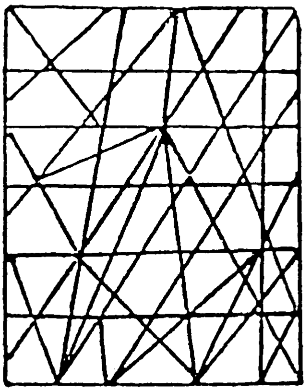
Find Simple Form "G"



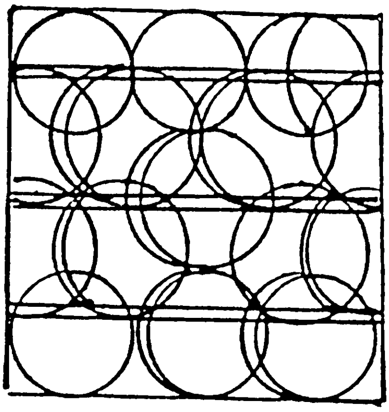
Find Simple Form "A"



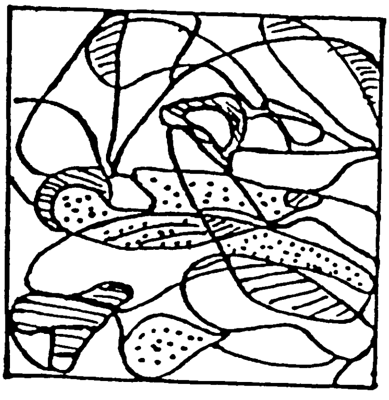
Find Simple Form "C"



Find Simple Form "D"



Find Simple Form "G"



Appendix 17 (b)

H. F. T SCORING KEY