COGNITIVE DEVELOPMENT AND TECHNOLOGY EDUCATION AT SECONDARY SCHOOL LEVEL:

MATCHING ABILITIES TO THE DEMANDS OF THE CURRICULUM

BY

Ewa Oboho M.Phil.

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University of Sheffield

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Dedicated to

Okon Ewa Oboho,

and all lovers of wisdom.

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ABSTRACT

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Ewa Okon Oboho

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This investigation was designed to explore the relationship between pupils' cognitive level of development and their response to design and technology curriculum. The purposes of the investigation were to (a) analyse the cognitive level of the pupils, (b) analyse the cognitive demands of design and technology in the National Curriculum, (c) develop a series of cognitively based questions dealing with design and technology, (d) determine whether pupils respond successfully to design and technology that was appropriately matched to their cognitive level of development.

To accomplish these goals, pupils from schools across two inner London Boroughs were selected. The investigator selected and analysed design and technology in the National Curriculum using a design and technology taxonomy developed for the investigation. The taxonomy was designed using a Piagetian-type framework and modelled after the taxonomy developed by Shayer and Adey. The investigator developed practical tasks and some written questions that were administered to the pupils. All responses to the investigator's practical tasks and written questions were recorded and analysed using not only the Structure of Observed Learning Outcome (SOLO) Response taxonomy, but also developmentally. Data from Piaget's test of formal reasoning was collected and compared to the pupil's performance in design and technology tasks.

The results indicated that (a) analysing pupil's responses to questions that were cognitively rated provided a developmental sequence of the characteristics of the different cognitive levels. (b) pupils will respond to questions that are matched to their cognitive level of development. (c) the pupil's cognitive level of development and not the age of the student are related to his/her mean cognitive level of response. (d) in predicting a pupil's mean cognitive level, the most significant variables will be the mean cognitive level of the question and the pupil's design and technology achievement. (e) a taxonomy for estimating the level of thinking demanded by design and technology can be developed. (f) pupils in the early years tended to repeat actions (operation) illogically, then become increasingly logical (systematically as they progress through the years. (g) technological thinking judged from the tests administered, involves factors that include 'general ability (intelligence)', 'perceptual analysis (spatial ability)', 'function/structure', 'practical ability', 'systematic/logical thinking', and 'science reasoning'. Curriculum implications for the development of design and technology curriculum, teaching and in-service training are drawn.

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CHAPTER 1

1.0 STRUCTURE OF THE THESIS

This thesis will attempt to relate the psychological characteristics of pupils to the demands of a technological curriculum. In pursuance of this aim, this thesis will be organised in the following way:

Firstly, the literature will be reviewed both from psychological and philosophical points of view, and from the point of view of the curriculum (technology). Based on this review, technological thinking tests/tasks will be developed and administered to pupils at KS. 3&4. Also, the basis of some of these tests/tasks will be examined. The pupils' responses to the tests/tasks will be subjected to psychometric, developmental and qualitative analyses.

Secondly, the curriculum (teaching and pupils' actual class work) will be analysed to determine the demands it makes on pupils at KS. 3&4. Both sets of evidence will be weighed side by side and curriculum implications drawn from the conclusions.

1.1 STATEMENT OF PROBLEM

Whereas a great deal of studies using a Piagetian-type framework, which attempt to match the learning demands of the curriculum to the cognitive development of the pupils, have been done in many areas of the curriculum such as Mathematics, (Collins, 1975), English, (Mason, 1974, p.124), History, (Hallam, 1970, p.3), and traditional Science subjects, (Shayer and Adey, 1981, p.1), 'Technology' subjects remain an area of the curriculum in which similar studies are lacking and urgently needed. (DES. 1988, p.6).

The urgency is not just because of the importance which has been attached to technology subjects in recent times, and the strong desire by teachers who teach them to want to know more about the processes involved in learning and understanding within the subject given its new conception, but also because of the apparent difficulty that many of the KS. 3&4 pupils who study these subjects, have with learning some aspects of the subject in schools. Donnelly and Jenkins (1992) and McCormick (1995, p.173), have confirmed that design and technology tasks make greater demands on pupils' conceptual and procedural knowledge than often realized. So too have certain organs of the UK education system i.e.. (DFEE 1994) and (OFSED 1995).

Thus, in an attempt to respond to this urgent need, this exploratory investigation, attempts to relate the psychological characteristics of the pupils to the demands of a technological curriculum. In the process, it is hoped that a framework will eventually emerge which can be of help to Technology teachers.

In those other areas of the curriculum which have been similarly studied using the Piagetian framework, one of the things that has emerged is the great mismatch between the curriculum materials and/or expectations institutionalised in courses, textbooks, and examinations etc., and the ability of the pupils to assimilate or understand the experiences given. That is, between the logical demands of what is to be taught, and the operations available to the pupils. In theory, this should not happen. This mismatch is part of the explanation given for the difficulty that the majority of the pupils had with learning these subjects, e.g., science. (Shayer and Adey, 1981). This may possibly be the case in 'technology' subjects in view of the apparent difficulty which the majority of the pupils in secondary schools have with learning some aspects of it. But the nature and extent of this mismatch is unknown. Waetjen (1989), in his review of the field, did not address the nature of the problems and difficulties. Kimbell & Stables (1995), have started to investigate the different experiences that pass for problem-solving in design and technology at secondary and primary levels.

1.2 SOME EXPLORATORY QUESTIONS

With respect to the theme of this investigation, one exploratory question which is to be considered is: (1) Could it be that the learners are presented with technological materials (teaching) that may be well beyond their ability or existing cognitive structures or thinking or, are teachers of technology subjects making 'reasonable' demands on their pupils? 'Reasonable demands', for the time being, means choosing curriculum materials which match with their pupils' power to understand them. This will involve the ability of the teachers to predict with a degree of certainty - just enough to increase significantly the probability of matching the material to their pupils' ability, that a class of pupils will not be able to assimilate a particular technological concept at a particular level, but, given the right teaching conditions, this class of pupils will be able to comprehend the concept at a certain level. Implied in the meaning of 'reasonable demands', is the expansion of pupils' cognitive level with teaching as an important factor. In other words, a demand if it is unreasonable, will be so called because pupils cannot immediately understand the material presented to them, but it is reasonable if the teaching fits in well enough with the pupils' conceptual level. In other words teaching and conceptual levels are integrated: so that the demand is not a question of challenge to the pupils, but that of expanding their cognitive level. For instance, if a teacher chooses material which is perfectly consistent with the pupils' ability to understand, then he/she has not taught anything new, because the pupils, in Piagetian terms, have just assimilated the material to an existing cognitive structure. Clearly, the teacher has to know about the cognitive level of his pupils. But the explanation of reasonable demand given above, is not a question of just getting the level of material right; instead, it is a question of presenting the material ahead of the pupils' existing cognitive structure.

This draws attention to the fact that teaching is an important factor which actually promotes the expansion of pupils' cognitive level, or promotes pupils' development, from one level to the next level (the Brunerian view), rather than just follows the child's cognitive level.

The other exploratory question which complements the first one above is: (2) Could there be a means of knowing or determining in advance which technological curriculum materials will be appropriate for a given group of pupils?

These questions implicitly call for a psychological model which will explain pupils' difficulties/failure, (as well as successes) and guide teachers not only in the selection of teaching and learning strategy, but also in the choice of materials.

PURPOSE OF THE STUDY

However, in order to tackle the exploratory and guiding questions posed above, this investigation will attempt to:

(a) examine the extent to which Piaget and other systems are useful for some traditional subjects, e.g. English, Literature, Maths and Science, and for technology subjects.

(b) establish typical levels of thinking in technology subjects and more specifically, answer the following questions:

  (i) will analysing pupils' responses, provide responses that can be categorised into each of the developmental levels and what are the characteristics of those response levels?

  (ii) will pupils respond with correct answers to questions when they are appropriately matched to their cognitive level?

(c) assess the level of cognitive demands made on pupils by technology curriculum activities. Can a taxonomy for estimating the level of thinking demanded by technology developed?

(d) Use the data from (b) and (c) above to ascertain whether the pupils will perform better when they are presented with materials which match with their level of technological thinking, i.e. determine whether pupils respond successfully to design and technology tasks that have been appropriately matched to their thinking (cognitive) levels of development.

This information can be used by teachers to select objectives and/or activities suitable or appropriate to a given group of pupils with a wide range of abilities, and also to rank levels of attainment within a topic according to the cognitive demands that they make.

1.3 BACKGROUND

In consonance with the concept of practical education, 'technology', in recent times, has been increasingly recognised and widely accepted as one of the areas of learning and experience in secondary schools' curriculum which should feature in a rounded education. Its wide-ranging influence and/or impact on almost every aspect of our lives, has been so tremendous and impressive, that many Governments have had to spend large sums of money on technology-related projects, with an implicit view to having or gaining a better insight into its dynamics, organisation and practices.

As will become apparent later, the recognition and subsequent inclusion of technology as a curriculum subject has been rather slow, partly because philosophers in the rationalist tradition, (e.g. Plato) did not consider it as an acceptable and respectable form of human knowledge relative to other forms of human knowledge, for example, Science and Mathematics. Another reason is that there has been less emphasis on 'practical' or (practical) education. However, it will be apparent in this thesis that philosophers concerned with the study of technology have demonstrated or re-emphasised the view that technology viewed from epistemological, anthropological and sociological standpoints, should be regarded as a form of human knowledge, a knowledge that can range from practical skills derived from concrete experience to a more general knowledge of how to cope with our environment. Metaphysical studies, notably by Dessauer (1956, p.234) and Heidegger and Jonas, (see Rapp, 1974)), have also concurred with this view. In these studies, knowledge has been involved centrally either as precondition or as product.

This view of technology, and the recent emphasis on practical education, can be seen to be implicit in a number of papers outlining National Educational thinking. This has made technology an important, interesting and exciting area for investigation. For instance, in the recent National Curriculum document for schools in England and Wales in design technology subjects, (DFEE 1995), the emphasis on 'practical' through problem-solving activity, is a deliberate attempt to develop technological competence in secondary school pupils.

As mentioned earlier, there have been difficulties in this attempt, and in the teaching of other areas of the curriculum such as Mathematics, History and Science subjects where pupils had similar difficulty. Attempts have been made to reduce it by matching the learning demands of the curriculum to the cognitive development of the learner, using Piaget's cognitive psychological model, (Fusco, 1983; Shayer and Adey, 1981). In the teaching of design technology subjects, the use of any psychological model in a similar manner is grossly lacking. Clearly, it would seem that what is needed is a model of cognition which will allow some predictions to be made about which technological activities are likely to be within the grasp of each pupil or a group of pupils.

However, theoretically, it is not unreasonable to suggest that the teaching of technology subjects can possibly be looked at very much in a similar way in a Piagetian sense, as in the teaching of Mathematics, Science, History and English reading. In other words, that same Piagetian type of logical analysis could be applied, to some extent, to the teaching of technology. The obvious question that springs to mind is, is it a possibility in the first place? However, in addition to Siraj-Blatchford's argument (1993, p.19-20) that a pedagogic model grounded in a 'moderated' version of Piaget (Constructivist, Vygoaskyian, Ausubelian) can be consistently applied throughout design and technology, if one looks at other areas of the curriculum where Piaget has been reasonably applied, then, one could admit the possibility in the teaching of technology subjects.

In these other areas of the curriculum, eg., English; History; Mathematics, there is a common belief, that if a teacher, who is reasonably knowledgeable in a particular area, can succeed in finding say, five, six, or even more process areas, that he and his colleagues think or value to be important or significant for the understanding (or development), in his/her subject area; in other words, if he can actually define five or more separable sets of basic skills, then, it is always possible, both theoretically and empirically, to define different levels of attainments within each of those. Furthermore, it is possible both theoretically and empirically to assess those levels of attainment in Piagetian terms.

Note that process areas or basic skills, in Piagetian terms, will be the operations that pupils carry out; i.e. schema and mental activity in transforming input into output. In analysing the ways in which knowledge of background information about a task could influence pupils' comprehension of that task. Strander (1979) stressed the following:

(1) the importance of schema as a general framework during encoding to facilitate the comprehension process;

(2) the responsibility of the teacher to determine what piece of knowledge or schema pupils must have in order to successfully comprehend tasks requirements;

(3) the need for the teacher to determine whether pupils have the background knowledge to understand and organise the task material.

The fact that schema guide comprehension has not been doubted. The schema theory acknowledges the interaction between the textual information and the pupils' schema. Inhelder and Piaget (1984), have identified and describe in detail the development of the schemata which evolve in each pupil. Learning to use this model is subordinate to development and a description of the schemata attained by the pupils can be revealed. The attainment of the schemata can be ordered hierarchically and generalizations made from the pupils studied to others.

Shayer and Adey (1981, p.4) developed a descriptive taxonomical model using Piaget's Schema which underlie pupils' thinking. This was organised by classifying objectives into groups according to schema and the characteristics of the stages of cognitive development. Although the taxonomy was constructed to analyse the science curriculum, it serves as a model for design technology and other disciplines. Pupils' performance can be anticipated when schemata comparing the curriculum and the characteristics of the cognitive levels of development of the students are considered and appropriately matched.

In English language and Literature where some of the things, (such as the notion of time, relative space etc.) overlap with things in science, some investigators have, with reasonable success, written out at least four or five lists of abstract processes, which every English teacher can recognise as being important for understanding concepts. Then, they have managed to define these abstract processes(schema), and the different levels in them. To illustrate the point, below is an example of English language process areas or skills (schema) and, in Piagetian terms, of the things considered to be involved in comprehending various texts of many kinds:

(a) Classification ability;
(b) Class inclusion ability;
(c) Seriation ability;
(d) Probabilistic notions;
(e) Relating cause and effect;
(f) Correctional reasoning;
(g) Combinatorial reasoning;
(h) Propositional arguments;
(i) Proportionality notions;
(j) Co-ordination of frames of reference:

Each of the above process areas or schema, can be described in Piagetian terms. Taking (a) above i.e.., - classification ability - for example, what is meant by late formal classification ability can be described, and specific examples, in terms of the texts to be given to pupils to work on, can also be given.

This is essentially what will be attempted in this exploratory investigation, with respect to 'design and technology', as described in the National Curriculum, (DFEE 1995). It will be noted from the new National Curriculum on technology that the new subject incorporates well-established yet different subjects ranging from metal work and motor vehicle studies to home economics and needlework (Sweetman. 1995, p.101).

For this investigation, however, technology courses would be so called where they meet all or some of the criteria listed below:

(1) be concerned with controlling the environment to meet human needs;

(2) allow pupils to be actively involved in the designing and making of artefacts, or devising working systems;

(3) deal with or consider problems which require the use of scientific knowledge, where necessary;

(4) help to build up in pupils a general understanding of technological concepts, particularly those which are related to energy, control, materials and communication.

It would appear that many people involved with technology seem not to know much about the process areas or skills in technology subjects. Although, as Siraj-Blatchford acknowledges (1993, p. 20), we have little knowledge about the design and technology process of cognitive development; the need to identify the very basis of "good practice" in design and technology is now urgent, especially with the introduction of British National Curriculum. At first sight, the dearth of information about the process skills in technology subject teaching has given rise to uncertainty about the usefulness of Piagetian stage theory. For instance, by looking at, say, a woodwork performance, one cannot be sure about the extent to which the process skills involved can be translated into Piagetian stages. This is probably because, in these subjects, reasoning of the sort involved in science is lacking. However, when it is remembered that beyond the realm of mere practical skill of which technology is normally conceived, intuition would suggest that before an intended useful technological product or result is achieved, there must be some form of reasoning, the possibility of such an application becomes apparent. The indication is that the process skills in technology subjects appear to be something that could be determined or worked out after, not before, the investigation.

Attempting a theoretical reflection only, in order to determine the process skills, can be an insurmountable task. Although theoretical reflection can be helpful in structuring where necessary, it shows the limitations of what can be gained through reflection.

The significance of identifying the process areas (or skill), is apparent particularly when it is acknowledged, as Polanyi (1958) did, that some of the pupils seem to have more knowledge than anybody has succeeded yet in describing: most technology subject teachers, who can teach technology subjects very well, may not have a good description of what it is that they are doing; they just do it.

Thus, from what has been said so far, the major task here, will be to produce these descriptions, for technology subjects, in the hope that at the end of this exercise, a glimpse of the theory and practice of technology, will be exposed more than as we know it at the moment. Furthermore, a description of the process skills in sufficient detail can be used both as an instrument for curriculum design and planning and also for assessing when pupils are making progress. In schools, teachers know how to give pupils feedback about their development of knowledge/learning, which is related for example, to subsequent performance in an examination. They know also how to tell a pupil whether he has done well. Undoubtedly, there is technological skill, just like academic knowledge skill, but they are not the same thing; and our (or any) system needs to be able to tell students when they are making progress, and when they have made progress. Unless, to reiterate, we have a good description of the process skills that we can rely on and can turn this into some form of assessment of pupils, they can be doing very good work, which they may not realise, and the teacher will not know that they have made progress.

Thus far, it has been intimated that Piaget has been tried in a number of subjects, and it is a very useful view. We do not know how to apply it in the teaching of technology subjects. It is my intention to do that; but to do it, I cannot theorise about it, I have to do the investigation first and then try to work out the Piagetian framework from there.

To set the stage, it is necessary to address the question: how useful is a general Piagetian type of analysis for specific subjects, such as English, Science or Mathematics?

1.4 DEFINITION OF TERMS

An understanding of the literature review which occurs in Chapter 2 will be facilitated by comprehending the following terms:

1. <u>**Cognitive Development**</u> - movement to, from and within the various levels of thought and reasoning described by Piaget.
2. <u>**Cognitive Stages**</u> - (as defined by Piaget) - Ages indicated are the ages at which the child normally functions within that stage.

    a) Sensorimotor Stage (birth to about age 2)
    Child learns through manipulating the environment at the perceptual level.

    b) Preoperational Stage (2 years to about 6 years)
    Child acquires symbolic thought.

    c) Concrete Operational Stage (6 years to about 11)
    Child develops logical structures to deal with changing objects in the physical world.

    d) Formal Operational Stage (11 years to adulthood)
    Child is capable of hypothetical and deductive reasoning of hypotheses and ideas.

3. <u>**Concept**</u> - In a logical sense, a mental construct of the generalizable aspect of a known thing.
4. <u>**Concrete Operations**</u> - a period characterised by the ability to deal with concrete objects in a logical manner. The major achievements of the concrete operational period are seriation, conservation and classification.

5. **Equilibrium** - Development is composed of conflicts and incompatibilities which must be overcome to reach a higher level, and thus equilibrium. (Piaget. 1964). It is the state of balance in which the organism's coherent/stable structures effectively interact with reality.

6. **Formal Operational** - A period characterised by the ability to deal with hypothetical reasoning. Formal operations are characteristic of the second and final stage of operational intelligence which reflects on concrete operations through the elaboration of formal group structures. The formal group structures include multiplicative compensation, probability, correlational reasoning, combinatorial reasoning, logic, proportional reasoning, the co-ordination of two or more systems of reference, mechanical equilibrium and forms of conservation beyond direct verification.

7. **Intelligence** - Problem-solving capacity based on a hierarchical organisation of symbolical representation derived from experience.

8. **Learning** - In the strict sense, acquisition of knowledge due to some particular information provided by the environment. Learning is inconceivable without a prior structure of equilibration which provides the capacity to learn.

9. **Schema - (schemata)** - A system or plan in which the connecting parts or thoughts are organised so that knowledge is realised.

10. **Social Cognition** - Characterised by experiences that are dependent on interpersonal relations in a social or cultural setting.

11. **Stages** - Successive developmental periods of intelligence, each one characterised by a relatively stable general structure that incorporates developmentally earlier structures in a higher synthesis. The regular sequence of stage specification activities is decisive for intellectual rather than chronological age.

12. <u>**Vectors**</u> - A line, such as an arrow, representing both the direction and magnitude of a force (e.g. water).

13. <u>**Simple Classification**</u> - The ability to group objects spontaneously by one attribute and to be able to shift to another attribute and re-group the same objects.

14. <u>**Two-way Classification**</u> - The ability simultaneously to co-ordinate two attributes of objects and to group objects by that co-ordination.

15. <u>**Three-Way Classification**</u> - the ability simultaneously to co-ordinate three attributes of objects and to group objects together which share three attributes in common.

16. <u>**Class Inclusion**</u> - The ability to understand and to co-ordinate in a hierarchical sense part/whole relationships.

17. <u>**Simple Seriation**</u> - The ability to order a set of objects along some relevant dimension such as size.

18. <u>**Double Seriation**</u> - The ability to order one set of objects according to some relevant dimension and to order a second set of objects along a relevant dimension in relation to that set of objects.

19. **Probability** - The ability to develop a relationship between the confirming and the possible causes with both beginning to be calculated as a function of the combinations, permutations, or arrangements compatible with the given elements.

20. **Correlational Reasoning** - The ability to conclude that there is or is not a causal relationship, whether negative or positive, and to explain the minority cases by inference of chance variables. The task for the subject is to find out whether there is a relationship between the facts described by two or more variables when the empirical distribution is irregular.

21. **Combinatorial Reasoning** - The ability systematically to generate all possible combinations of the givens when a problem's solution demands that all possibilities be accounted for.

22. **Logic** - The ability to reason using propositions based on a formal system.

23. **Proportional Reasoning** - The ability to discover the equality of two ratios which form a proportion.

24. **The Co-ordination of Two or More Systems (Frames) of Reference** - The ability to co-ordinate two systems, each involving a direct and inverse operation, but with one of the systems in a relation of compensation or symmetry with respect to the other. This represents a type of relativity of thought.

25. **Mechanical Equilibrium** - The ability simultaneously to make the distinction and the intimate co-ordination of two complementary forms of reversibility - inversion and reciprocity.

26. <u>**Forms of Conversions beyond Direct Verification**</u> - The ability to deduce and verify certain conservation from its implied consequences. Developing a chain of inferences by which the conservation can be verified by observing its effects only.

27. <u>**Prestructural**</u> - Student avoids the question (denial), repeats the question (tautology), a firm closure based on transduction. Transitional - student attempts to answer the question but only partially grasps a significant point.

28. <u>**Unstructural**</u> - An answer is based on only one relevant aspect of the presented evidence so that the conclusion is limited and likely to be dogmatic. Transitional - an attempt to handle two aspects of the evidence is made, but they may be inconsistent and hence no firm conclusion is reached.

29. <u>**Multistructural**</u> - Several consistent aspects of the data are selected, but any inconsistencies or conflicts are ignored or discounted so that a firm conclusion is reached. Transitional - any inconsistencies are noted: several aspects are recognisable but the student is unable to reconcile them.

30. <u>**Relational**</u> - Most or all of the evidence is accepted, and attempts are made to reconcile. Conflicting data are placed into a system that accounts for the given context.

31. <u>**Extended Abstracts**</u> - There is recognition that the given example is an instance of a more general case. Hypotheses about not given examples are entertained, and the conclusions are held open.

SECTION - TWO ~ LITERATURE REVIEW 1

CHAPTER - 2

SYSTEMS FOR DESCRIBING PUPILS' THINKING WITHIN COGNITIVE PSYCHOLOGY

2.1 INTRODUCTION

Since research work which directly and/or specifically examines the relationship between the psychological characteristics of the pupils and the demands of a technological curriculum is virtually non-existent, the best that can be done in this circumstance, is cautiously to extrapolate some pertinent aspects from studies of a similar nature in other areas of the curriculum such as Science, Mathematics, English Language, etc.

In these other areas of the curriculum, such a relationship has given rise to the idea of 'matching' the curriculum to the pupil's cognitive level, i.e.., adapting the instruction to the learner's current level of operation or thinking. This constitutes the main aim of this thesis. However, this idea of matching seems to have been given a new impetus following the work of Jean Piaget on cognitive development. Indeed, this is one of the practical issues raised by this work. The usefulness of Piaget's developmental model, as will be shown later, is in providing us with (1) a framework for understanding curricular design; (2) a system for understanding curricular design; (3) a basis for the schema theory's descriptive perspective for understanding the development of children's capabilities in design technology. Shayer and Adey (1981) have demonstrated the applicability of this model to the science curriculum.

In section 1, it has been pointed out that a good description of the 'process skills' in technology is the key to knowing which technological thinking the pupils use in solving problems in technology subjects.

It has also been pointed out, that by determining these process skills, it will be possible, both theoretically and empirically, to define levels of attainment. Studies which have concerned themselves with the relationship between the pupils' psychological characteristics and the demands of the curriculum, have adopted either the Piagetian approach or its alternative. However, in both of these 'basic' approaches, the necessity for producing a detailed description of the pupils' thinking has been uppermost. In summary, the literature review will focus on three areas:

(1) **Cognitive development** - this was an important component of the investigation, since a Piagetian perspective was used as a framework.

(2) **Survey of design and technology and response studies** - to provide insight into the pupils' involvement and understanding of the tasks requirements.

(3) **Survey of studies related to contextual analysis** - to provide insight into the knowledge structures present in design and technology.

It is worth noting, that with respect to technology subjects, the 'process skills' are not something which can be entirely determined or worked out before the investigation. But instead, they can partly be determined after the investigation and partly by reflection. Before examining the method to be used in eliciting these process skills, it is appropriate to dwell a little on the various methods or systems for describing pupils' thinking, which exist within cognitive psychology, as well as the curriculum areas in which they have been successfully applied. It must be borne in mind, that within these various systems, a procedure for eliciting the process skills is suggested and the importance of the relationship between children's responses and their cognitive level (thinking) underlined. Thereafter, school subjects and responses studies will be looked at. Then, in Section 3, an examination of the nature of technology as a subject in secondary school will be undertaken, so as to have an insight into the knowledge structure present in it, as well as the pupils' involvement and understanding.

The relevance of the theories of cognitive and conceptual development to design and technology is found in the idea expressed by Kimbell et.al.(1991) in their research on modelling as part of the essence of design and technology. Pupils need to have a model in their minds before it can be expressed or developed further on paper or other media. Without this they cannot be clear about what their ideas are. This implies some sort of mental construction.

2.2 COGNITIVE DEVELOPMENT STRUCTURALIST AND MECHANISTIC-FUNCTIONAL (NON-STRUCTURALIST) SYSTEMS.

It can be said, that within what is referred to as the 'structuralist' framework, two principal systems for describing pupils' thinking exist, and can be identified by their root metaphors.

In one, (referred to as the classical structuralist scheme), the root metaphor is the growing biological organism. This is the organismic structural approach (and its universal stages). Piaget, Kohlberg, Kaplan, etc., are the proponents of this system. In the other, (the alternative scheme), the root metaphor is the machine. These alternative schemes are based on cybernetic principles and are referred to as "mechanistic-functional" (non-structuralist) approaches (and their individual differences). Biggs and Collis, Case, Pascual-Leone, McLoughlin, etc., are proponents of this scheme.

2.3 THE CLASSICAL STRUCTURALIST SCHEME

2.3.1 GENERAL INTRODUCTION (REVISITING PIAGET)

However, with respect to the classical structuralist scheme, the most and widely known within education is Piaget's psychological mode. Piaget's theory of cognitive development became widely known and useful, because it constituted:

> "an alternative to the numerous and the unlearn postulates
> and corollaries associated with Hullian learning theory."
> (Bolton, 1986, p.235)

His main interest has been to try and elucidate the nature of knowledge: (particularly the development of scientific knowledge); how it is that knowledge is structured; and whether or not all concepts can be reduced to simple bits of information. As an epistemologist, he puts forward the view, that the development of concepts is as a consequence of the development of logico-mathematical structures. But there was a shift in his relatively late works from this position to one that asserts that human knowledge and the person who knows are intimately related, and so he proceeds to study the former by looking at the way in which it is assimilated by the latter.

He and his associates then gather information on the performance of children and adolescents in many tasks, most of which involve the manipulation of physical materials. This information is to give the researchers insight into how children develop their understanding of aspects of the physical world such as time, space, motion and matter. They also conduct interviews and observe pupils. His intention in gathering this information is not to develop a theory of the structure of the mind, but a theory of the structure of knowledge by gathering such information from a child's birth to the age of sixteen. Logically, this will lead to the development of a theory about the development of cognition in the child, rather than a theory about the development of the child. In effect, the suggestion here is that there is a "strong" relationship between the structure of knowledge and the mental structure of the person who knows.

However, by establishing a growth in the child's ability to perceive, process, and use data, Piaget is implying that there is a hierarchy of complexity in the possible ways in which data may be processed. This may well mean a hierarchy amongst level or comprehension demanded by a set of learning material. At this point, it is appropriate to examine very briefly some basic concepts in Piaget's systems, if insight is to be gained about the characteristics of this approach. Then, some of the curriculum areas where it has been used to facilitate teaching and learning will be reviewed.

2.4 SOME OF PIAGET'S BASIC CONCEPTS

INTRODUCTION

The difficulties in understanding Piaget's own writing are obvious to any first-time reader. One difficulty arises partly because his theory has been evolved largely in isolation from the main Western tradition of psychological research. As a consequence, most of his terms cannot be translated easily, but he uses them in a manner which leaves to the reader the task of teasing out their full meaning for his own purposes. Another difficulty in understanding Piaget has to do with the fact that his concepts are very abstract, to the extent that they are at some 'distance' from the factual observation, and this renders the specification of the operational link difficult.

However, in spite of these difficulties, the importance of his concepts (which are distinctively biological in flavour), lies in the potential which they have in conveying a whole perspective on behaviour which is unique in contemporary psychology, relative to the prevailing psychological orthodoxy.

2.4.1 ACTION

Before Piaget, underpinning the bulk of psychological research, has been a conceptual analysis of behaviour in terms of stimulus and response. Therein, the stimulus (which may be external or internal) has a function, which is to evoke a behavioural response. When the interest is in investigating the causes or determinants of behaviour, such conceptual analysis is inevitable. However, it carries the implication of relative passivity of the organism, until stimulated into behaviour, and downplays the self-directing and self-regulating aspects of human functioning. In contrast, Piaget takes the view that the organism is living and active, and that every event that occurs between it and the environment is conceived as being, at one and the same time, the action of the organism upon the environment, and the action of the environment upon the organism. His viewpoint implies an epistemology - a way of interpreting the child's knowledge of his world.

By rejecting two extreme alternatives, namely, (1) that the child is somewhat like a tabula rasa, who passively receives and retains information coming to him, and (2) that the child inherits a kind of performed knowledge of the world which matures with age, and which filters and organises incoming information in its own terms (i.e., inherited and fixed reflex-responses in the child), Piaget takes a middle position.

This position allows him to assert, that in simultaneously acting upon the environment and being acted upon by it, the child actively CONSTRUCTS his knowledge of the world.

Thus, acting upon the world is knowing it; and knowing the world is acting upon it. In two main ways, Piaget's use of the term "action", far extends beyond its usual meaning. Firstly, ALL FORMS OF PERCEPTION are seen as actions upon the world, as a way of assimilating it. Secondly, activities such as thinking, remembering, and dreaming, are construed also as actions upon the environment, although, in symbolic and internalised forms. So that by subsuming overt behaviour and thinking under the category of action, Piaget is declaring a functional continuity between them. This is vital for his theory.

2.4.2 COGNITIVE STRUCTURE

According to Piaget, all action (overt or internal) has form, and this is, to a large extent, a function of the structure of the organism in action. Although the action cannot be repeated in exactly identical form, there is sufficient approximate repetition to justify the inference that the underlying structure is relatively stable and lasting. Piaget regards these structures as cognitive because of his interest in the knowledge and intelligence implied in action. A baby who grasps a ball held in front of him is KNOWING the ball in a very primitive sense, as something which has to be grasped, because he cannot possibly know it any other way. Far from expounding a cause and effect approach to behaviour, Piaget follows the structural-functional type of explanation: explaining the way structures change in terms of their functioning.

2.4.3 SCHEMA AND OPERATION

With reference to cognitive structure, Piaget makes use of two terms, SCHEMA and OPERATION. He regards SCHEMA as the basic unit of structure. Because he uses the terms loosely, and freely, he does not relate it in any precise way to behaviour.

Nevertheless, he appears to mean the structure underlying a simple unitary act, for example, picking something up, looking at something or remembering something. OPERATIONS are regarded as SCHEMATA which have become organised into highly stable systems displaying distinctive logical properties. For example, the possession of operational structure enables the older child to have insight into a number or to classify objects and people in a hierarchical fashion.

Consideration of these two terms discloses one of the major weaknesses of Piagets theory, because they are concepts which relate Piaget's abstract theorising to behaviour in an impressive manner.

2.4.4 ASSIMILATION, ACCOMMODATION AND EQUILIBRIUM

Whereas action is regarded by Piaget as the functioning of cognitive structure, the form which it takes is also a function of the environment acted upon (directly or symbolically). Thus, cognitive structures are being modified in some ways by the environment in the very process of functioning.

In accordance with this thinking, the action of a child can only be in terms of his existing cognitive structures, their level of complexity and organisation. In other words, the universe only exists for him insofar as he has cognitively structured it, but of course, the world is always more complex and problematic than the child's existing structure or knowledge of it can cope with or allow. Thus, in acting upon the environment, the child's structures are constantly developing in complexity. The limits on the rate of this development are set by the nature of human system, and its capacity to mature and change. Furthermore, the starting point of this change must always be the point which the child has currently reached.

What follows from the above, is that the condition which facilitates cognitive growth is the presence of the unfamiliar and puzzling in the context of what is familiar and known. Piaget's accounts of the dual influence of structure and environment upon action, and the simultaneous development of structures are explained, in terms of ASSIMILATION AND ACCOMMODATION.

Assimilation refers to the use which cognitive structures make of aspects of the environment in their own terms and for their own purpose, during action. For example, a baby grasping a ball. In becoming something to be grasped, the ball is assimilated to, or becomes, "food" for the grasping schema. Accommodation, on the other hand, refers to the adjustment to the thing being assimilated which the cognitive structures are forced to make, during the process of assimilation. So that the baby's grasping schema has to adjust to the size, weight and texture of the ball.

All actions, whatever their level of complexity, involve both assimilation and accommodation. Whereas assimilation is the conservative element, accommodation, is the element of change. The extent to which the environment can be assimilated sets limits to the extent to which accommodation can occur. The predominance of one aspect over the other is possible. Play, fantasy and dreaming represent primary assimilatory activities, although they also impose some measure of accommodation. Conversely, imitation and mental imagery are primarily accommodatory activities. Piaget maintains that the most intelligent adaptation to the environment occurs, at whatever level of development the child has reached, when those aspects of action are in balance or EQUILIBRIUM.

Although the concept of EQUILIBRIUM is difficult to grasp, it appears to imply a condition of stable balance. The origin of Piaget's notion of equilibration is in his biological ideas of man as an adaptive organism.

> ....., this adaptation is a state of balance ...... between two inseparable mechanisms: assimilation and accommodation. We say, for example, that an organism is well-adapted when it can simultaneously preserve its structure by assimilating into it nourishment drawn from the external environment and also accommodate that structure to the various particularities of that environment: biological adaptation is thus a state of balance between an assimilation of the environment to the organism and an accommodation of the organism to the environment. Similarly, it is possible to say that thought is well adapted to a particular reality when it has been successful in assimilating that reality into its own framework while also accommodating that framework to the new circumstances presented by the reality. Intellectual adaptation is thus a process of achieving a state of balance between the assimilation of experience into the deductive structures and the accommodation of those structures to the data of experience.
>
> (Piaget 1970, but see Driver 1981. p3.)

The learner as an active "creator" of his or her own knowledge is implied in the quotation above. This is a notion which was embraced and nourished in this country's and elsewhere (Australia Primary Science). This view of the child learning naturally through his/her interaction with the environment, has in fact been expressed by earlier educators, notably Rousseau, Froebel and Dewey. But by going beyond mere statement of principles to outlining in some detail the nature of the development which a child undergoes, Piaget set a precedent.

However, Piaget uses the concept EQUILIBRIUM in at least four distinct but related ways.

Firstly, he uses it to characterise cognitive structures within the individual when these form a tightly knit and stable organisation, as in operations. According to this use of the concept EQUILIBRIUM, the characteristics of adult world such as time, causation, and space, as well as the existence of objects and people etc., are self-evidently so to use because we possess cognitive structures in a state of equilibrium.

Secondly, he uses the concept to describe the relationship between the organism and the environment, when the former has achieved a stable adaptation to the environment.

Thirdly, he uses the concept to describe the stability between accommodation and assimilation, which is evident when actions upon the environment are realistic and effective.

Fourthly, besides states of equilibrium, Piaget also refers to the PROCESS OF EQUILIBRIUM. By this, he appears to mean, that total process whereby the organism-environment relationship moves forward throughout development, towards that most comprehensive and far-reaching level of adaptation that the organism's genetic endowment permits. However, the mechanism by which equilibration occurs is not specified by Piaget. Nevertheless, from his seemingly inadequate description of the process of equilibration, it can be concluded that the process of development must of necessity be a rather slow one. Just as one will not expect a child to develop an adult identity in a few months if he is simply given hormone treatments to induce maturation or exposed to a massive variety of new physical and social experience to induce learning, so one cannot expect a child to develop an entire system of formal thought in a few months simply by the action of maturation of learning. Because the 'equilibration process is an internal one that involves reflection, co-ordination, and construction.' (Case, 1985 p.170).

Equilibrium, according to Piaget, occurs through the assimilation and accommodation of structures. It permits us:

> to reunite into one and the same totality those two aspects of behaviour which always have a functional solidarity because there exists no structure (cognition) without an energiser (motivation) and vice versa.
>
> (Piaget, 1974 p.301).

Piaget, it will be recalled, is not interested in the kind of equilibrium where the child withdraws from the problem, but instead, in the kind of equilibrium that results when the child has acquired a new way of thinking to deal with the problem. This way of thinking or operation should be an operation which we rather hope is going to be an operational structure: i.e. is going to be some organised logical skills, such that he/she knows not only how to solve that problem, but also similar problems. (We look for a transfer of learning).

Though it is not clear whether or not Piaget uses the term "transfer of learning", it appears that he hopes to find it, just as anyone finds intelligence when one finds transfer of learning. Thus, the basic thrust behind equilibration is the maturation of the organism, but the process of equilibration mentioned above, is an interactive one between the organism and the environment.

2.4.5 PIAGET'S METHODOLOGY

Having briefly looked at Piaget's general purposes and conceptual approach, it is logical therefore that his general methods of investigation be also briefly examined. His aim (as it is all too familiar) has been to map out the development of cognitive structures from childhood to adolescence. Standardised tests have been instruments which he did not consider useful at the initial stage, because they do not tap the riches of the child's thinking process. He instead opts for the method of clinical interrogation, which he has used not with young infants, but with older ones. As he cannot interrogate a young infant verbally, he acts towards him in certain ways, or presents him with simple problems and observes how he behaves. For instance, he may make certain gestures and see whether the child tries spontaneously to imitate them, or he may place a toy which the child wants out of his reach, but on a cushion which is within his reach and see what the child will do about it. These sorts of tasks are given to an infant at a time when he has to stretch his skills and capacities to the limit, for only then can Piaget see what resources the child has available. Older children are presented with problems, but these are augmented by fairly intensive verbal questioning.

Indeed, vital to Piaget's purpose, is that his methodology will reveal the basic reasoning and thinking processes of the child. It is a fact that, as a child grows older, his own natural thinking processes are likely to be masked by the knowledge, ideas and verbal formulae which he picks up from others, and especially adults. This presents a problem for Piaget, but he manages to offset it by presenting the child with problems, in material and verbal forms, which are new to him, and which, in many cases, he cannot be expected to solve adequately. This will inevitably force the child to fall back on his resources and his thinking process will then surface. Thus, the child's wrong answers are more informative about his thought processes, than his correct ones.

Piaget (1929), classifies the verbal responses which young children give as:

(1) **Random**: where the child is not interested in the question, and says the first thing, more or less, which comes into his head;

(2) **Romancing**: (which develops from the above) where the child impulsively gives an answer to a question, which he apparently believes more and more as he gives it, but which he rapidly forgets afterwards, by giving a different answer to the same question;

(3) **Suggested Conviction**: where the child, anxious as he is to answer the question, picks up some cues therefrom, and bases his answers upon them;

(4) **Liberated Conviction**: where the child grapples with the question in terms of his existing capacities and thinks his way through to his "real" answer;

(5) **Spontaneous Conviction**: based upon liberated conviction, the child gives an answer confidently and readily.

He proposes several criteria for sifting out the last two kinds of responses. According to Piaget, the occasions when we are confident that we are tapping the child's own cognitive structures are when:

(1) he resists counter-suggestion and sticks to his answer;

(2) the logical form of the child's answer remains consistent, if the same problem is approached in several different ways;

(3) the logical form of his answers remains the same for other allied problems;

(4) the same logical form can be discerned in the responses of many children of about the same age and this form differs from that of children of other widely different ages.

Piaget presents his findings in such a way as to allow him to state, in general terms, the features of cognitive structures which he thinks he has elicited, and then goes on to illustrate these statements with samples of extracts from interview protocols. Very rarely does Piaget present any statistical evidence of the frequency of particular responses at a particular age. He neither makes clear the line of inference from observed responses to the implied nature of cognitive structure, nor does he often consider alternative constructions that could be put upon the child's responses.

There are indications from the interview protocol that Piaget frequently broke his own rules for interviewing children. He will give the same problem to different children but the interviews which follow will vary quite widely from one child to another. In spite of these and other criticisms of Piaget's reported work, as discussed later, it is clear that his own empirical investigations can be regarded as pilot studies used to support his theoretical standpoint, rather than as controlled and systematic attempts to test its weaknesses.

It is clear from the above that responses as vehicles for knowing something about pupils' thinking are extremely important.

2.4.6 THE STAGES OF DEVELOPMENT

From what has been said so far, it is true up to a point that the development of cognitive structures consists of the steady and progressive elaboration and organisation of schemata. Nevertheless, Piaget insists that his empirical findings demonstrate that this progressively increasing complexity of structural organisation is marked by a sequence of "break-throughs" into a qualitatively new form which functions in ways that are not predictable from earlier forms. The child's world, as it is directly and self-evidently perceived in his consciousness of it, passes through a sequence of transformations as he grows up. Indeed, his adaptations to the world develop through a series of evermore comprehensive and stable equilibria. This stepwise aspect of cognitive development engendered Piaget's use of the concept of STAGE.

The use of the term STAGE, must not be confused with age, because the age at which children move from one stage to another may vary stage in such a way that it is grossly inaccurate to speak of a child as being at a particular STAGE.

This is so because the implication is that he exhibits a characteristic in all aspects of his living and the evidence shows clearly that this may not be the case. For a child may reach a given stage in his mathematical thinking, or in his conception of the object, but he may not have reached the same stage in his social thinking or in his concept of volume. Piaget has built into his theory the idea that once a child breaks through into a qualitatively new level of thinking in one area, his acquisition of this level in other areas is much easier. This phenomenon he calls HORIZONTAL DECALAGE.

In any event, it is both empirically and logically necessary for Piaget that the sequential ordering is held to be INVARIANT. For some people, due to their cultural or inherited factors, develop more slowly and less far than others. Nevertheless, the order of the stages through which they go remains the same for all people. According to Piaget, the characteristics of one stage are not left behind, but are taken up into the next stage, transformed and made more complex.

Thus, broadly speaking, cognitive development can be seen as a movement from egocentricity to decentration. This occurs at three successive levels, as discussed below. For Piaget, egocentricity means, a state whereby there is no clear distinction between self and other, or between subjective and the objective. The child is unable to conceive yet a perspective other than his own. The movement out of egocentricity consists of the acquisition of a sense of an objective universe in which the child can locate himself as one particular among many.

2.4.7 SENSORIMOTOR STAGE (0 to 2 years approximately)

From Piaget (1951, 1954) we learn that a child is born already equipped with a number of basic action patterns (schemes) such as grasping, sucking and visual tracking. Accordingly, the child acquires his first knowledge of the world, by exercising these schemes (skills). And immediately after he/she acquires his/her first knowledge, two basic changes take place in the schemes themselves, namely, differentiation and co-ordination. In other words, these schemes themselves become more differentiated (i.e. become capable of being applied differentially, to a wider variety of objects), and co-ordinated (i.e. being initially relatively isolated and reflexive, they gradually become co-ordinated with a large number of schemes such as manual seriation etc.). By applying and co-ordinating these sensorimotor schemes, the child not only acquires a multifaceted and stable understanding of the objects in the immediate environment, he/she also acquires a flexible system of sensorimotor operations, through which he/she can acquire further knowledge of new objects in new environments. In other words, the infant develops a conception of the environment as existing independent of itself.

This is a limited sort of practical intelligence. The characteristics of the system of sensorimotor operations, are such that any effect produced by one scheme (say grasping), can be reversed by another scheme (for example, replacement). Note, that "scheme" is a Piagetian term; it does not mean a conscious plan, it is more like a skill, for example, the scheme of grasping, the scheme of following a moving object with one's eyes. These "schemes" (skills) develop in the Sensorimotor period. In summary, Piaget has postulated that during the stage of Sensorimotor intelligence, the child learns to:

(1) co-ordinate perceptual and motor functions;

(2) utilise certain simple schemata with external objects;

(3) use simple forms of symbolic behaviour.

However, the major conquest at this stage, is that of objects.

2.4.8 PERIOD OF PREPARATION FOR AND ORGANISATION OF CONCRETE OPERATIONS (2 to 11 years approximately)

2.4.8(a) Sub-Period or Pre-operational Representation (2 to 4 years approximately)

The next six years of life (i.e. between the age of two and eight), sees a parallel trend to the Sensorimotor stage (i.e. first 2 or 3 years of life) appearing, but this time at a higher level. (Piaget, 1952, 1960, Inhelder and Piaget, 1964). The child having mastered the basic Sensorimotor operations which are pertinent to his/her immediate environment, begins to represent these operations symbolically (through language, mental imagery, and the ability to draw) and to manipulate objects both mentally and physically. The similarity of the new schemes which a child develops during this period (pre-operational) with those which were developed during the Sensorimotor intelligence stage, is in the fact that they (the new schemes developed) can still be applied only in the presence of, or on, concrete objects. But the difference lies in the fact that these new schemes now involve actions that can be described as more internal (mental) in character, for instance, procedures for combining and manipulating words, procedures for classifying objects, and procedures for quantifying. At first, the symbolic schemes that emerge are (like the Sensorimotor stage) rather global and isolated. For example,

> the mental activity of finding the larger of the two objects would be based on global appearances and would not yet be co-ordinated with the reciprocal activity of finding the smaller of the two objects. (Case 1978, p.169)

In a typical Piagetian experiment (Piaget, 1952), the child in this stage will be shown a box containing a large number of brown and a small number of white wooden beads. When asked if there are more wooden beads, he/she will reply that there are more brown beads. This behaviour is typical of a child who is unable to perform the operations of abstraction and inclusion, which are required in the formation of a logical system of classes. (This stage is called the pre-conceptual substage of the pre-operational stage).

2.4.8(b) Period of Intuitive Intelligence (4 to 7 years approx.)

However, later, these symbolic schemes, once again (as in the Sensorimotor stage) become more differentiated and co-ordinated, so that by the age of approximately six to eight, the child has begun to form a new system, exemplified by the intuitive intelligence. During this stage, the child acquires the concept of permanence of quantity. In a typical Piagetian experiment to demonstrate this, two glasses are filled to the same level with a coloured liquid. The liquid from one glass is poured into a tall narrow cylinder, and the child is asked if the amounts are still the same. The five year old will likely state that the amount is unchanged. In order to reach this conclusion, the child must perform two basic operations. Firstly, he/she has to decentre his attention from one aspect of the situation so that he understands that a process of compensation has taken place. Secondly, he/she must have developed the intellectual structure which allows reversibility to take place, i.e. the water can be returned into the glass without any change in volume.

2.4.8(c) Sub-Period of Concrete Operations (7 to 11 years approx.)

Thus, during the years from two to eight, as well as acquiring the knowledge of basic categories and relations of relevance in their environments, children also acquire a system of concrete operations through which they can acquire further knowledge of this sort in new environments. The basic characteristic of the concrete operation is that the effect of any one mental action (e.g. width increase) can be reversed or compensated for by some other mental action (e.g. width decrease, or height increase).

However, approximately between the ages of seven and eleven years, the child's system of concrete operations become increasingly stable and generalised. Simultaneously, the foundation for the emergence of a higher order mental operation is laid. (Inhelder and Piaget, 1958). These higher order mental operations take the products of the second state (i.e.. the mental operations of the preceding stage) as building blocks and operate on objects. The mental functioning of the child during the concrete operational state, is such that when he/she witnesses and increase of weight on one arm of a balance, a simple negation of this effect by the subtraction of the same amount of weight, can be imagined by him/her. There will also be an understanding of the reciprocal effect produced by an addition of weight to the other side. In effect the child is actively able to operate on external objects. The major conquests during this stage are those of conservation, seriation, and classification. By using these systems, the child is liberated from the strictures and limitations of pre-operational stage; he can now disassociate his actions from their effects. This liberation however, is only of a partial nature, because, although he now has available to him a series of logical operations, he can only use these operations in isolation from each other. When faced with problems which require the simultaneous use of two or more operations he is unable to reach a solution. This is attributable to his inability to combine these systems into a single integrated system. As a forerunner for formal operation, the child in the concrete operation is supposed to be capable of sorting out objects in a fashion which has been described in symbolic terms by Inhelder and Piaget; namely, given two classes A1 and A2, with either complementaries (things that do not belong in A1 and A2), A1" and A2", concrete class logic furnishes only four elementary products. (A1*A2, A1*A2", A1"*A2").

2.4.8(d) The Period of Formal Operation (from 11 years approx.)

This is the period of acquisition of formal operations, that is, reversible mental operations upon propositions, hypothetico-deductive thinking, formal reasoning. Reality becomes subordinate to possibility. Propositional logic according to Piaget, depends upon a 'combinatorial system', and this is associated with the group of operations called the INRC group.

Children at this stage of development (i.e.. formal operation) are thought to be capable of taking either the operation of negation or reciprocity as a starting point for the generation of the others mentally in the absence of any concrete instance. Furthermore, they are thought to be capable of taking relation between these two relations as a given, and imagine an inverse relation between relations in some other variables such as the distance from the fulcrum of the beam balance. By applying and comparing operations, children become capable of generating possible combinations in a given situation and with this a procedure for experimentally eliminating all combinations except one, in order to isolate the effect of one particular variable.

In other words, besides acquiring an understanding of the world that is more abstract and complex, the adolescent also acquires a co-ordinated system of formal operations, through which he/she can acquire similar abstract knowledge in new content areas. However, during this formal operational stage, the adolescent learns to use hypothetical reasoning based on the logic of all possible combinations. Clearly, in this stage, there is a shift of emphasis from the real to the possible suggesting that the individual has developed a cognitive strategy which can be brought into use to enable him/her to determine reality within the complex organisation of the possible. It is this strategy which allows him/her to use a mode of reasoning which is hypothetico-deductive in nature. He/she is now able to reason by the separation of the real from the hypothetical. He/she constructs hypotheses which incorporate all the data available; these he/she examines, rejecting those which do not fit into the context of the problem, whilst moving those which do conform to the domain of reality. And as will become apparent later on, the problem-solving nature of design and technology subjects requires the pupils to determine the problem, generate possible solutions, and then choose the most suitable one. The reasoning mode employed is similar to the one mentioned above.

Thus, the thinking of the individual is now characterised by its propositional quality; he is no longer limited to concrete operations. He/She is able to use those operations to manipulate the raw data, and then to form the results of these operations into propositions, upon which he/she carries out a further set of operations. These features of Formal Operations, are accounted for in terms of symbolic logic, in his Meta-theory. According to Piaget's Meta-theory, in formal operations, we are concerned typically with propositions; (statements) and relationships between statements. Such that by taking the two propositions (not classes or objects as in concrete operations) (p = it is red) and (q = it is square), with their negations (p" = it is not red) and q" = it is not square), formal logic furnishes sixteen (16) possible combinations, derived from four (4) elementary propositional conjunctions (possibilities). (see the illustration on page 38)
It must however be stressed, that Piaget's use of logic here, is different from anybody else's. He writes in such a way as to make one think that is using conventional logic. However, Piaget's idea concerning formal logic furnishing sixteen possible combinations, allows us to penetrate, as it were, into the structure of formal operations. And by way of expounding this idea, an interesting arrangement of it (i.e. the sixteen possible combinations), has been presented by (Richmond 1971).

PIAGET'S SYSTEM OF SIXTEEN BINARY OPERATIONS - A DIAGRAM.

	p	$\bar{p}$
q	+	+
$\bar{q}$	+	+

16.

	p	$\bar{p}$
q	+	+
$\bar{q}$	+	o

12.

	p	$\bar{p}$
q	+	o
$\bar{q}$	+	+

13.

	p	$\bar{p}$
q	+	+
$\bar{q}$	o	+

14.

	p	$\bar{p}$
q	o	+
$\bar{q}$	+	+

15.

	p	$\bar{p}$
q	+	o
$\bar{q}$	o	+

8.

	p	$\bar{p}$
q	+	o
$\bar{q}$	+	o

6.

	p	$\bar{p}$
q	+	+
$\bar{q}$	o	o

7.

	p	$\bar{p}$
q	o	o
$\bar{q}$	+	+

10.

	p	$\bar{p}$
q	o	+
$\bar{q}$	o	+

11.

	p	$\bar{p}$
q	o	+
$\bar{q}$	+	o

9.

	p	$\bar{p}$
q	+	o
$\bar{q}$	o	o

2.

	p	$\bar{p}$
q	o	o
$\bar{q}$	+	o

3.

	p	$\bar{p}$
q	o	+
$\bar{q}$	o	o

4.

	p	$\bar{p}$
q	o	o
$\bar{q}$	o	+

5.

	p	$\bar{p}$
q	o	o
$\bar{q}$	o	o

1.

Truth tables for the sixteen binary operations of propositional logic.

The diagram above is derived from A.L. Baldwin's exposition of Piaget, but has been arranged in a way suggested by P.G. Richmond.

From this arrangement, suppose one wishes to find the evidence against the idea, If p, then q. (i.e. possibility fourteen), one would be looking for something that was red and not square. This would be the evidence against the idea If p, then q. Richmond's diagram shows, that the evidence against the idea in question, is possibily no.3 in the diagram. One can get from no. 14 to no. 3 by swinging a supposed or imaginary pointer in the middle around 180 degrees. This no. 3 is called the negation of no. 14, and the process is the finding of negation. In Piagetian thinking, as no.3 is the negation of no.14, so also is no. 14 a negation of no.3. And similarly, no.4 is the negation of no.13. However, possibilities no.13 (if q, then not p) and no. 14 (if p, then not 1), respectively, are referred to by Piaget as reciprocal. He says that no.13 is the reciprocal of no. 14; no.4 is the reciprocal of no.3; no.11 is the reciprocal of no.6.

Note that it is not important to know why Piaget uses the terms reciprocal, and rather than trying to justify him we should expound him. So, in Piaget, we find these two relationships, negation and reciprocal. They are relationships between relationships. There is yet another relationship called correlative. Piaget says, that no.14 is the correlative of no.4.

The final relationship is identity. This means leaving things where they are. For example, if p, then q, is identical to if p, then q. (i.e. red is red: a chair is a chair). These relationships namely, identity, negation, reciprocal, correlative, are related in some way, and collectively called the INRC or INCR group.

Furthermore, a simple electrical apparatus can be used to describe the logical structure of formal operation. This description resembles the coloured liquids experiment used by Piaget. Consider the possibility of a board onto which has been mounted a bulb Z and a switch A, (see fig. a).

The logical possibilities under which the bulb will light are as follows: (a) the bulb Z lights when switch A is up (b) the bulb Z lights when switch A is down. This can be represented symbolically, viz., (a) Z = A (b) Z = A" Imagine that there is a further board onto which has been added a second switch, (see fig. b). The possibilities raised by this extra switch are as follows:

(a)	Z = A*B	(i.e. switch A up, B up)
(b)	Z = A"*B	(" " A down, B up)
(c)	Z = A*B"	(" " A up, B down)
(d)	Z - A"*B"	(" " A down, B down)

These possibilities can be represented by the expression

Z = (A*B) + (A"*B) + (A*B") + (A"*B")

The possible associations symbolised by the above expression are the product of a one-to-one class multiplicative system, which represents the attainment of concrete operations stage. The inverse of the system, i.e.. the conditions which will cause the bulb not to light, are beyond the child's at this level. Only at the level of formal operations will the child be able to invert reality. Increase in the number of switches as in fig (c), results in an increase of the variables inherent in the problem. At the concrete level, the subject can handle these variables by the above process, but each variable must be considered in isolation from the others: he cannot as yet, consider their combined effects. The individual operating at the formal operations level, approaches the problem differently. The associations (A*B) and (A"*B) are regarded by him as propositional and, consequently, do not have class significance. They are representations of hypothetical statements which he can experimentally verify. The products of the concrete multiplicative operations are now hypotheses, upon which he can carry out 'second order' operations.

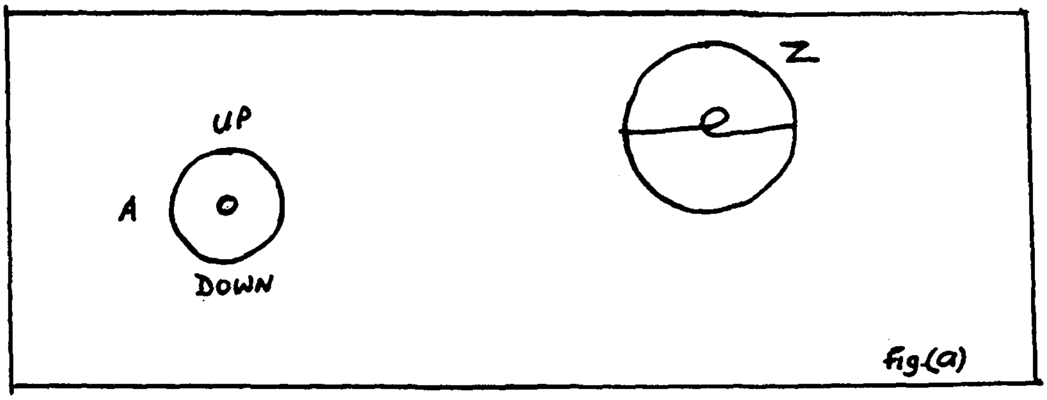
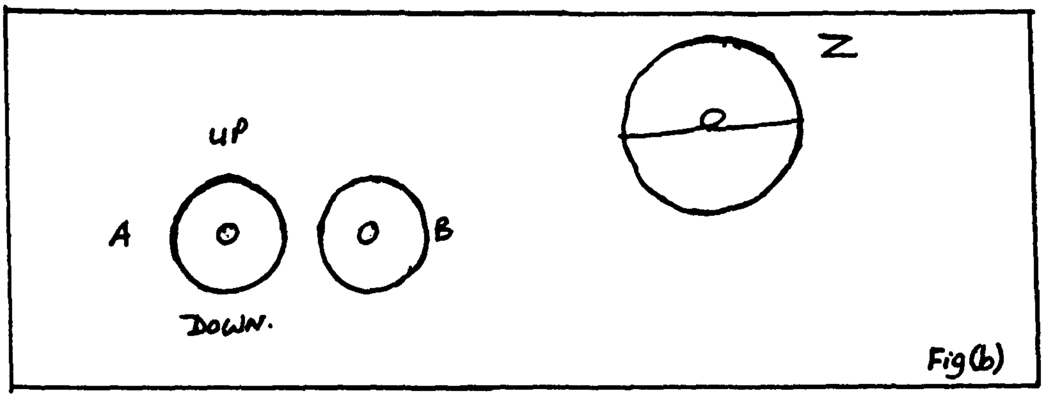


Fig.(a)



Fig(b)

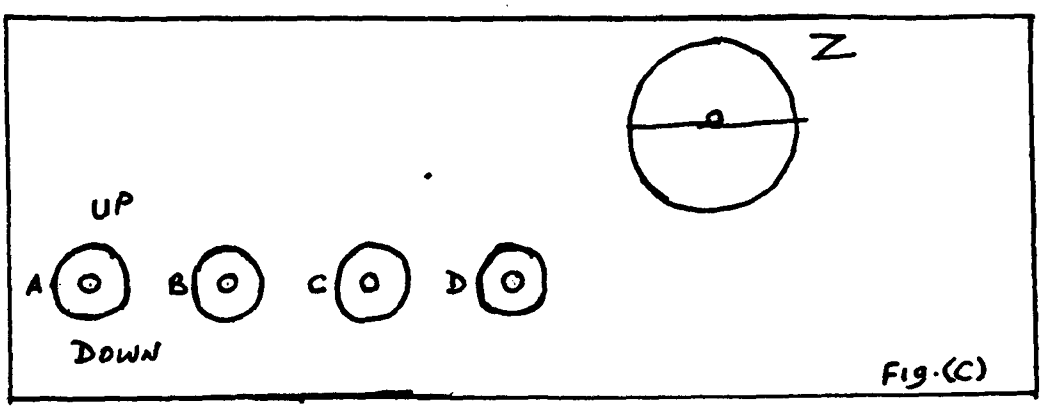


Fig.(C)

SIMPLE ELECTRICAL APPARATUS.

Z = BULB.

A,B,C,D = SWITCHES.

This change from intrapropositional to interpropositional operations has been represented in the language of symbolic logic. Accordingly, the symbols A and A", become p and q is true, and q" is not true). The class multiplication signs (*), are replaced by the conjunction sign (.), and the addition signs by the disjunction sign (V). The reversed notation for the four possibilities is as follows:

(a)	(A*B)	becomes,	p.q
(b)	(A"*B)	"	p".q
(c)	(A*B")	"	p.q"
(d)	A"*B")	"	p".q"

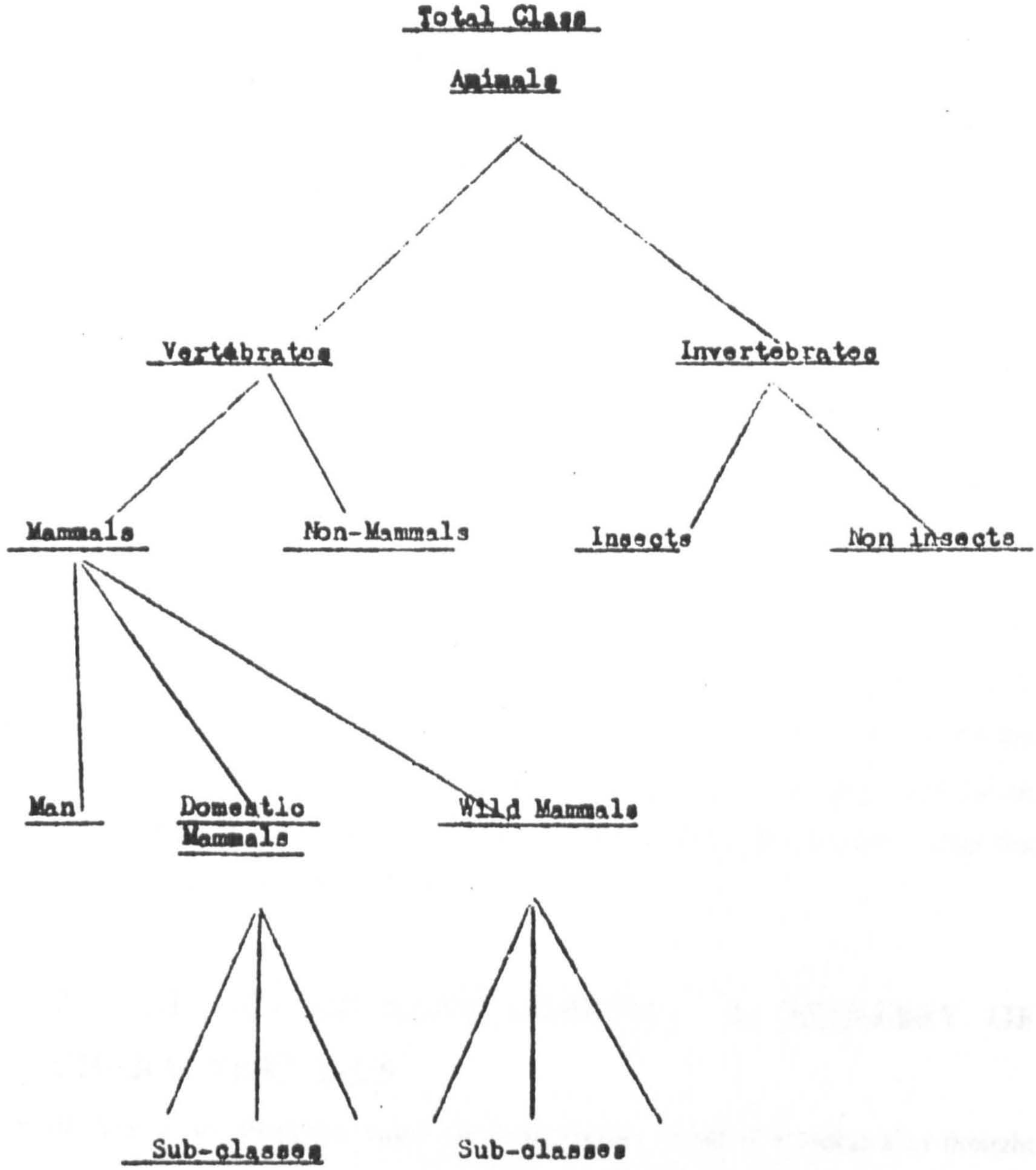
The statement p.q means that both are true. Similarly, p V q, means that either p or q is true, or that both are true. Its meaning can also be expressed by (p.q") V (p".q). The only possibility which p V q denies is p".q" (the possibility that neither is true). It is clear that the four base associations used above are conceived as possibilities, and have been represented as letters a.b.c.d. From these four associations there are sixteen distinct possible combinations (See fig. d). The sixteen combinations come about by taking the four base associations, and combining them one by one, two by two, three by three, four by four. This set of sixteen combinations provides the description of the 'lattice' type of structure common to formal operation thinking.

However, the alternative explanation to Piaget's Meta-theory, seems to suggest that, actual human thinking is richer and more varied than any logical calculus can [possibly] model. (Shayer and Adey,1981, p.26) This alternative explanation to Piaget's Meta-theory, based on the principles of cybernetics, has been put forward by McLaughlin (1963), Case (1974) and Pascual-Leone and Goodman (1979). There is no

Number	Base Association	Binary Propositions
1	0	$(p \cdot q) \vee (p \cdot \bar{q}) \vee (\bar{p} \cdot q) \vee (\bar{p} \cdot \bar{q})$
2	a	$p \cdot q$
3	b	$p \cdot \bar{q}$
4	c	$\bar{p} \cdot q$
5	d	$\bar{p} \cdot \bar{q}$
6	a+b	$(p \cdot q) \vee (p \cdot \bar{q})$
7	a+c	$(p \cdot q) \vee (\bar{p} \cdot q)$
8	a+d	$(p \cdot q) \vee (\bar{p} \cdot \bar{q})$
9	b+c	$(p \cdot \bar{q}) \vee (\bar{p} \cdot q)$
10	b+d	$(p \cdot \bar{q}) \vee (\bar{p} \cdot \bar{q})$
11	c+d	$(\bar{p} \cdot q) \vee (\bar{p} \cdot \bar{q})$
12	a+b+c	$(p \cdot q) \vee (p \cdot \bar{q}) \vee (\bar{p} \cdot q)$
13	a+b+d	$(p \cdot q) \vee (p \cdot \bar{q}) \vee (\bar{p} \cdot \bar{q})$
14	a+c+d	$(p \cdot q) \vee (\bar{p} \cdot q) \vee (\bar{p} \cdot \bar{q})$
15	b+c+d	$(p \cdot \bar{q}) \vee (\bar{p} \cdot q) \vee (\bar{p} \cdot \bar{q})$
16	a+b+c+d	$(p \cdot q) \vee (p \cdot \bar{q}) \vee (\bar{p} \cdot q) \vee (\bar{p} \cdot \bar{q})$

<u>Sixteen Binary Propositions formed from Four Base Associations.</u>

The Lattice Structure of Classes.



attempt to question the operations which Piaget has identified. Instead, they are offering a different interpretation of them.

As will be made apparent later, both systems accept the existence of operational structures. They conceptualize them in terms of sets of schemes, which reflect previous knowledge and govern the acquisition of new knowledge via their control of the equilibration process. Whereas Piaget thinks that these structures can be modelled as logical competence, and subsequently expressed in symbolic logic, the alternative position is that these structures can be modelled as:

> sets of executive schemes whose releasing cues and sequences of effecting acts can be inferred directly from children's performance.... (Case, 1978, p.192).

However, despite some compatibility between the notion of logical structure and executive schemes, the content of the latter can possibly be specified more easily and concretely than logical structure, according to (Case, 1978). By this conceptual shift, it is believed that children's thought can be modelled in a more detailed and precise manner; it is more closely tied up with observed behaviour. This line of thought will be taken up later.

2.5 STAGES OF DEVELOPMENT: A SUMMARY OF CHARACTERISTICS

All in all, four major Piagetian stages (with substages) of the development of thought (or how an individual comes to understand increasing by complex structures), can be delineated from the above examination. They are, as will be seen in a number of texts on this subject, and subsequently mentioned here, namely: sensorimotor stage; preoperational stage; concrete operational stage; and the formal operational stage.

As already been mentioned, the sensorimotor stage, is the period from birth to about two or three years of age. In this stage, the infant (1) learns to co-ordinate perceptual and motor functions; (2) utilise certain simple forms of symbolic behaviour. During this stage, the major conquest by the child is the conquest of objects. The period that extends immediately from sensorimotor stage until about six or seven years of age, is generally referred to as sub-period preoperational representations. This is a period during which the child beings symbolically to represent the external world through language. The child demonstrates this mainly by generalising, and the major conquest during this stage is that of language, mental imagery, ability to draw etc. Then comes the sub-period of concrete operation, which manifests itself between the ages of seven and eleven years. During this stage, the child is actively able to operate on external objects. The major conquest here is that of conservation, seriation, and classification. Finally, the formal operation represents the third major stage, and manifests itself from the age of eleven years approximately. This is the stage at which the adolescent acquires formal operations, i.e.. reversible mental operations upon operations, hypothetico-deductive thinking, formal reasoning. Here, reality, is subordinated to possibility. And according to Piaget, propositional logic depends upon a "combinatorial system", and this he says is associated with a group of operations known as the INRC group. In other words, formal operations are characteristic of the previous stages of operational intelligence, which reflects on the concrete operations through the elaboration of formal group structures (i.e. INRC). The formal group structure includes multiplicative compensation, probability, correlational reasoning, logic, propositional reasoning, the coordination of two or more frames (or systems) of reference and mechanical equilibrium.

Thus, the adolescent develops formal operations, which are organised internal mental activities performed upon statements (or propositions). He/she becomes able to propose hypotheses and to test them systematically. He/she becomes aware of a set of possible states of affairs within which exists the one actual state of affair. In other words, the use of hypothetical reasoning based on the logic of all possible combination is what the adolescent learns during this stage.

Thus, it can be seen that, apart from the sensorimotor period, the rest of the periods are operational, because they involve a type of action to be carried out directly or internally by the individual. Inhelder and Piaget (1958), accordingly assert that:

> an operation differs from simple action or goal directed behaviour in that it is internalised and reversible (eg. adding or subtracting, joining or separating). It is an action which is bound up with others in an integrated structure. (p. xiv)

The integrated structures are presumed to depend upon the stages of development, and can be related to a special group of logical forms of structures. Thus, whereas the concrete operations stage depends upon the logic of classification (class inclusion), seriation, one to one correspondence, and conservation, the formal operational stage depends upon the logic of combinatorial operations, proportions, co-ordination of two systems of reference, and the relativity of motion or acceleration, the concept of mechanical equilibrium, the notion of probability, the notion of correlation, the forms of conservation which go beyond direct empirical verification and multiplicative compensation. (Inhelder and Piaget, 1958 p.310-329). The operations that are of real interest in school years are those characterised by concrete and formal thought.

2.6 VARIABLES WHICH ACCOUNT FOR PROGRESS FROM ONE STAGE TO ANOTHER

Piaget claims that there are four factors or causes, which affect the child's progress through the developmental stages. These are (a) maturation, (b) experience, (c) social experience of socialisation and (d) equilibration. (Piaget, 1964).

(a) **Maturation:** This is very open, and not unambiguously defined by anyone. What is usually referred to as maturation includes some process or processes that go on independently of the outside world; i.e.. something that goes on in the individual, according to his biological nature. Note, that environment also affects maturation; eg. the child would need food (nutrition), for maturation (and survival).

(b) **Experience (Activity):** This is subdivided into three namely, (i) simple exercise; for example like practising sucking or reflex, activity is improved (ii) physical experience: which consists of extracting information from objects themselves. (knowledge) (iii) Logico-mathematical experience: for example, counting forward and backward. (Action plus knowledge).

(c) **Influence of social environment**: for example, education.

(d) **Equilibration:** this is an organising factor which co-ordinates other facts. (self-regulation).

None of these factors is considered sufficient for the development of thought; all of them play an important part in the process. Having said this, Piaget seems to regard equilibration as the most important of these four factors. Because, despite the fact that he concedes the necessity of the other three factors, the exact mechanism by which they exert their influence or effect, is not properly treated or defined, and their importance is consistently downgraded. (Piaget, 1964, 1970). As was mentioned earlier, Piaget is also vague in his explanation of the process of equilibration. (Piaget 1964, 1970, 1971).

2.7 USEFULNESS OF PIAGETIAN STAGE THEORY

The implications of Piaget's work for curriculum materials and the teaching of particular school subjects, have been enormous. For example, practising teachers readily invoke the "readiness" concept; that it is not worthwhile to instruct children in material which requires thinking at a higher stage than that at which they are currently capable of thinking (algebra, for example, may not be attempted until a certain age 13 years). Furthermore, inductive teaching with much use of concrete material is to be used for children, and there should be less talk and chalk.

In the early and middle 1970s, authors including, in History, de Silva (1972) and Hallam (1967, 1969, 1970); in Geography, Rhys (1972), in English Literature, Mason (1974); in Mathematics, Collis (1975, and Lovell (1971); in Science, Shayer et. al. (1976), have all held onto the fact that internal logical structures guide behaviour. To the extent that any error in the responses of children at different stages, is indicative of natural developmental phenomena, rather than the result of "carelessness", inadequate learning, or poor teaching. All these researchers must be greatly indebted to the notion of the coherence of the stages.

They maintain, that taking account of what the learner already knows [what Ausubel (1968) refers to as prior knowledge], in terms of the cognitive operations available to him, can ensure some permanent learning. And if a mismatch between the logical demands of what is to be taught and the operations available to the learner exists, then permanent learning will hardly take place. Anderson (1968) (see Driver, 1982, p.357), has shown this to be plausible.

2.7.1 HOMOGENEITY OF THE STAGES

The idea of "Matching" arises from the implications of Piaget's stages thus, that

> the operation characteristic of each stage becomes integrated and consolidated. (Driver 1982, p.356)

so much so that they have internal coherence before significant development in operation, typical of the next stage, takes place. However, there have been confirmations about the internal coherence of the stages. Lunzere (1965) reviewed the homogeneity of the stages and confirmed the unitary nature of concrete operation. Lovell (1961), using about ten Piagetian tasks as described in the Growth of logical thinking, Inhelder and Piaget (1958) was in sympathy with this idea of internal coherence of the stages. The research by

Lawson and Renner (1974), Lawson and Norland (1976), and Shayer (1979), supports this notion. The factor analytic study carried out by Lawson, et. al. (1978), which involved the use of tasks involving propositional logic, propositions, probability, and correlations, is supportive of the notion of homogeneity of the stages and also worthy of mention. However, for Berzonsky (1968), Hughes (1980), and Brown and Desforges (1977), the notion of internal coherence of the stages is unfounded.

Although the notion of internal coherence of the stages has received considerable attention by researchers, because of its potential, and practical values in education, the Meta-theory used by Piaget to explain the homogeneity of the stages has been queried by Parsons (1960), Bynum, et. al. (1972), and an alternative explanation offered by McLaughlin (1963), Pascual-Leone et. al., and Case (1978). Yet, efforts to exploiting its potential have continued. For example, attempts have been made to match the logical demands of a curriculum to the operational capabilities of the pupils. Such attempts, as in Shayer and Adey (1981, p.26), have acknowledged the difficulties, uncertainties, etc., involved in Piaget's Meta-theory. Instead, they have concentrated on that dimension of Piaget's Protocol (2nd tier) which allows for the observation of children: for example, watching their performance and monitoring their responses at times in natural settings, but often in problem-solving situations. This involves the actual description of the pupils' responses, (which are accounted for by the cognitive structures or operations available to the learner). Then these descriptions are appropriately categorised.

This appears to be a fair alternative in response to the difficulties shown to be associated with the Meta-theory. These difficulties arise because the Meta-theory is thought to have the power to predict human behaviour. Lawson and Karplus (1978) stated that Meta-theory was evolved by Piaget, as a means of explaining the logic involved in the ten schemas which he described as underlying the performance of children in different tasks. These schemas are as follows:-

- control of variables,
- exclusion of irrelevant variables
- combinatorial thinking
- notion of probability
- notion of correlations
- co-ordination of frame of reference
- multiplicative compensation
- equilibrium of physical system
- proportional thinking
- physical conservation involving 'model'.

Thus, the inability for the Meta-theory to produce falsifiable predications cannot justify the rejection of the whole gamut of psychological description produced by Piaget and his associates. By way of suggesting a fair quantitative test for Piaget's Meta-theory, Shayer and Adey (1981), lay their emphasis not on the predictivity of behaviour, but on the consistency of the schema. In this respect, they introduced three levels of explanation or description, for the unity of formal operation. Whereas one level is extremely qualitative, another is extremely quantitative. Between these extremes, is a level (2nd tier mentioned above) which allows for the observation of children.

2.7.2 MATCHING MODEL

2.7.2(a) Science Subjects

Science is considered here because of its strong relationship with technology, as will be demonstrated in that section of this work which deals with technology and its meaning for education.

The evidence of the coherence of the stages has led to the concept of matching. Science 5 to 13 (in England) and (ASEP) in Australia, are the two curriculum projects which have been designed such that materials are presented to the pupils according to the cognitive demands which they make. Teachers who use these curriculum materials are given instructions on how to diagnose the level of thinking a pupil is capable of, and thus how to select material which matches in order that development may be stimulated. Implicit in this programme, is the notion that pupils' learning depends on developmental level, and there are other studies within the area of science, to demonstrate this too. They include the study by Lawson and Renner (1975), wherein a mismatch has been identified between the logical demands of secondary science courses and the developmental level of the pupils. Sayre and Ball (1975), with a combination of interviews and Piagetian tasks, assessed the level of thinking of the Junior and Senior grade (14 to 18 year olds), and demonstrated that the scores obtained on the tasks correlated with the grades obtained in science courses. Shayer and his associates have done a considerable amount of work using the matching model. Shayer and Adey (1981) have attempted to relate the psychological characteristics of the pupils to the demands of science curriculum. They were hoping to establish an "appropriate" match, after previous research (Shayer et. al., 1976) had indicated that there was a considerable mismatch between the logical demands of the curriculum and the cognitive capabilities of the pupils. Shayer and Adey (1981, p.72-79), identified about nine process areas in science subjects by (reflection) using Piaget's protocol, and proceed to define different levels of attainment within each of these areas.

> They end up with a method for estimating the level of thinking demanded by science curriculum activities. Based upon their report about an empirical study in which pupils' performance on tasks assessed to be at a late concrete level can be predicted from their performance on group- administered Piagetian tasks, they recommend this test instrument for use by teachers for assessing the cognitive level of their pupils. Furthermore, they report a correlation of 0.77, which suggests that about 60% of the variance in the score can be predicted on the basis of these Piagetian tests. (Shayer, 1978).
>
> However, (Driver 1982, p.359), has reasons to be cautious about Shayer's report. After expressing her worries about the....'reliability of the analysis of the cognitive demand of
> the curriculum materials themselves",

she seems to think that it is not inconceivable, that the level ascribed to any lesson topic may depend on the teacher's interpretation of the material and the approach used. In other words, the issue involved is pedagogical rather than curricular. A particular topic may be treated in such a way as to demand formal operational thinking. Generally, in practice, we are most likely to find that most teachers would treat a particular topic in a manner that requires concrete operational thinking.

2.7.2(b) English Language/Literature Subjects

In English language, where some aspects such as the notion of relative space, etc., overlap with those in science subjects, some investigators have, with reasonable success, written out at least four or five lists of abstract processes, which every English teacher recognises as being important for understanding. Then, they managed to define these abstract processes, and the different levels in them. In English Literature, Fusco (1983) identified eight process skills required for the understanding of various tests. They are (1) Classification ability; (2) Class inclusion ability; (3) Seriation ability; (4) Probabilistic notion; (5) Relating cause to effect; (6) Correlational reasoning; (7) Combinatorial reasoning; (8) Propositional arguments; (9) Proportionality notions; (10) Co-ordination of frames of reference.

Each of the above process areas is then described in Piagetian terms. Taking Classification ability as an example, what is meant by late formal classification ability is described and a specific example, in terms of the texts to be given to pupils to work on, is also given.

She used this information to analyse (1) the cognitive level of the students in secondary school, and (2) the cognitive demands of the literature text books. Her reports tend to suggest that children are more likely to perform better where there is a match between their cognitive level and the cognitive level of the literature text books.

Adey (1979), minimised the difficulty which pupils had with the learning of some aspects of science subjects (physics), by first determining the cognitive levels of both the pupils and the curriculum and appropriately matching them, using Piagetian protocol. However, the (potential) advantages of matching the operational capabilities of the learner to the logical demands of the curriculum material have been expressed by many. In English Literature, Hunt (1961), like Shayer and Adey (1981), stressed the importance of "matching" the learner to the material, and accordingly asserts that

> the environmental circumstances force accommodative modification in schemata only when there is an appropriate match between the circumstances that a child encounters and the schemata that he has already assimilated into his repertoire. (p.268.)

He points out that critical periods occur when this appropriate match is achieved to promote optimal growth. According to Hunt, during this period,

> accommodative modifications in central structures take place when the child encounters circumstances which so match his already assimilated schemata that he is motivated by them and can cope with them. (p.280)

Matching process, according to Hunt (1961) is vital in teaching because through it the necessity arises for the analyses of the already assimilated schemata of the pupil and the newly presented task or circumstance. But he recognises the problem involved since such assessment could only be obtained through observing behaviour, listening while the pupil expressed him/herself on a particular matter, and from knowing the individual's past experiences. There is a further need to analyse the pupil's potential intellectual ability. The description of successive stages of intellectual development by Piaget removes the necessity for some trial and error in determining the appropriate match. (p.287)

Elkind (1974) (see Fusco 1983, p.30) has been concerned with the problems that occur when education is inappropriately matched with the child's intellectual and emotional development. He reviews the work of Piaget and reports that the child's thinking grows both by substitution (i.e., by replacing a less mature idea with a more mature one), and by integration (i.e.., less mature ideas are brought together to arrive at more complex and abstract conceptions). This growth was always in the same direction ~ toward ever greater objectivity, reciprocity and relativity.

> Case (1985, p.27) acknowledges the 'goodness' in the matching concept, yet he insists, that because of the rational and empirical problems engendered by the notion of logical structure, attempts at matching learners' ability to the curriculum are problematic. They are problematic because, one will need to specify what logical structure is of relevance to the subject area in question.

Furthermore, 'successful' matching would necessitate the assessment of the presence or absence of this structure in the pupils. Neither of these, according to Case (1985) is easily achieved because of the abstractness of Piaget's theory and the presence of decalage. Nor is Stewart (1979) satisfied with Preece (1976), Shaeffer (1980), and Shavetson (1974) who used concept mapping and word association, to ascertain what the learner already knows (semantic words). He seems to think that these authors in fact assessed semantic proximity, i.e.., words which tend to be associated in semantic memory.

In spite of the advantages offered by the matching model, Piaget's stage theory is limited and has come under attack.

2.8 CRITICISMS OF THE STAGE THEORY

Piaget's stage theory has come under severe attack by his critics. The main difficulties with Piaget's theory, which his critics always point to, are those associated with the assertion that development of children is controlled by the emergence of general logical structures, (i.e.. the notion of a logical structure), and that transition from one stage of development to another is as a result of the process of equilibration.

With respect to the notion of a logical structure, two major attacks are made purely from the rational viewpoint. One the one hand, the abstractness and the difficulties operationalizing the concept is much in evidence (Brainerd, 1973, Flavell, 1963). On the other hand, the logical model proposed by Piaget contains mathematical or logical errors (Ennis, 1975).

Empirically, the problem of horizontal decalages showed quite clearly.

In any case, in criticising the "structure d'ensemble" (i.e..the structured whole of each stage), what his critics have done is to decompose his hypothesis of structured whole into its principal empirical criteria, namely, universality and synchrony.

Such decomposition opens Piaget's hypothesis to attack (Fisher and Silvern, 1985, p.632). In questioning whether the implied need for the synchronous appearance of a set of behaviour as evidence of a stage made any meaningful sense, Modgil and Modgil (1976) quote Brainerd (1973) as having expressed the opinion that

> ..... if we take the constant operation of the groupments as the defining attributes of a particular stage of mental development (as Piaget does) the predictions of the synchronous emergence of operations within groupments are psychometrically inescapable.

However, it is worth remembering that Piaget hypothesised that all children will show high synchrony in the sequence across domains, at least at each age when a new structured whole shows. Synchrony requires a child who has developed concrete operations in one type of conservation (say, of amount of water) simultaneously to develop concrete operations in others (say, of length of string). Indeed, the structured whole should induce concrete operational structures simultaneously in tasks involving schemes other than conservation: eg., classification, seriation, and number (Inhelder and Piaget, 1964). The strictest interpretation of the structured whole hypothesis requires that the child develops concrete operations in all domains at virtually the same point in time, thus demonstrating what can be regarded as "point synchrony". However, this has not been found to be the case. Biggs and Collis(1982) and Flavell (1982), have shown that children manifest high unevenness or decalages. This has even been acknowledged by Piaget (1971) who asserts that this unevenness cannot be explained. And as Broughton (1981) concurs, within the structuralist scheme, this variation is difficult if not impossible to explain.

Amongst the studies which have reported asynchronism in the appearance of responses characteristic of the same stage, is Lovell and Ogilvie (1960), who report that a significant number of children who conserve rubber band substance, cannot conserve plasticine. This is not in tune with Piaget's hypothesis of synchrony. Even in their later studies about conservation of weight, Lovell and Ogilvie (1961) report that, although most children manifest the logical operations of transitivity of weight relations and reversibility over shapes, they still have problems with conserving weight, particularly due to the fact that they have interfering beliefs about the effects of other variables like hardness, warmth, dryness, etc., on weight. The authors conclude by asserting that conservation difficulties cannot be explained in terms of logical mental structures.

Smedslund (1961), in a similar work in which the relationship between logical operations and conservation is implied, reports that transitivity of weight (as an example of a logical operation) failed to occur simultaneously with conservation of weight, (as an example of infra-logical operation) amongst a group of 408 5 to 7 year olds.

Uzgiris (1964), reports that although children conserve substance, weight, and volume etc., there are individual differences between the children regarding the order in which the different materials are conserved, a variability which she thinks is accounted for by their individual past experiences.

Lunzer (1960) is suspicious of Piaget's attempt to associate observed behaviour with underlying psychological processes, and demonstrates that the pupils' ability to calculate volume from dimensions is perhaps more associated with their ability to understand proverbs than to concepts of infinity and continuity. The appearance of somewhat similar skills in pupils of the same age range is not evidence for causal connections between skills:

> Complexity of logical structure demands a parallel complexity in the corresponding psychological process. But the two structures are not necessarily identical, and it is the second which is fundamental to the cognitive development of children. (Lunzer, 1960, p.198).

Furthermore, two hundred and forty 5 to 10 year olds have been studied by Dodwell (1960) for acquisition of number concepts. The results show many examples of asequential development of responses reminiscent of three stages:-

- A (global comparison)
- B (intuitive stage)
- C (operational stage)

Besides, the chances of a child who is at stage C for cardination and ordination being found to be in stage C for seriation were slim: only 0.56. Furthermore, the probability of the same child being in stage B for seriation is 0.45.

By citing a number of studies, the majority of which concern either the acquisition of formal operations in different task situations, or show evidence of "precocity" (the production of what is considered an advanced level of behaviour by a child thought to be at an early state), Brown and Desforges (1977) launch a ferocious attack on the concept of stage.

For instance, they cite Neimark's results (1975) which show a correlation of about 0.4 between measures of formal operations based on tasks involving permutations and combinations. But they seem to have ignored the conclusion drawn by Neimark, namely,

> This evidence provides extremely strong support for Piaget's stage theory of cognitive growth..... There is evidence for concrete and formal stages of task strategy with transition from concrete to formal through temporary intermediate levels.

Brown and Desforges (1977), also cite Schwebel's studies of (1975) in which three formal operational tasks have been performed independently of one another. The conclusion from the results indicate that formal operational stage presents a particular kind of problem, regarding the equivalents of the ability of individuals at different tasks.

The evidence of precocity used by Brown and Desforges for attacking the stage concept has been provided by Gelman and Tucker (1975), whose report shows that children estimate the number of a few objects shown for a short while by counting, while Piaget (1952) suggests that the process is more perceptual.

Piaget's concept of equilibration has formed another line of attack by his critics on the concept of stage theory. For Piaget, the individual stage represents a stage of equilibrium, with the transitional stage between the main stages representing the states of disequilibrium. This state of disequilibrium is thought to be engendered by cognitive conflict. And cognitive conflict in turn is vital for the process of development. It is in the area of training that cognitive conflict has been most useful. So much so that some research has reported that a cognitive conflict training (Piagetian training) can be more effective than other types of training. It is interesting to note that Piaget shows interest in teaching by saying something about it. But he has not done much research into teaching or training. It is not out of place to say that it is part of the tradition of child development theorists not to be interested in research into teaching and training. Developmental psychology has grown up with people studying the children as if there is no training involved. Although Piaget himself has not published any study about training, some people who have worked with him like Inhelder et.al. (1974) have published a book reporting experiments in which children have been supposedly trained.

But Brainerd (1973), in his review about the question of training or acceleration studies, has cited instances of training techniques which have not involved cognitive conflict. Yet they are as effective as cognitive conflict in inducing

> temporarily durable, generalisable, conservation in the quantity area plus considerable for transfer to other concept area. (p.360)

Generally speaking, those who have used standardised techniques in 'conflict' situations, get

> "poorer results than direct training techniques." (Vuyk 1981, p.376)

These results, however, are not without problems.

Novak (1978) reviews data from a number of studies about the development of concepts in cross-sectional samples of six to fifteen year olds and has been led to report the absence of obvious evidence of stepwise development because the data show a more or less smooth increase with age in the proportions of pupils achieving each concept, with no apparent evidence for stepwise development.

These criticisms have paved the way for other conceptions of the 'stages', to which attention will be turned shortly.

2.8.1 STAGE AS A FUNCTION OF WORKING MEMORY AND GENERAL ABILITIES

It has already been mentioned that levels of development depend to a great extent on the particular task presented to the pupils. However, this does not mean that there are no endogenous limitations to what they can do. In Piaget's theory, general abilities are in some way related to developmental stages. Working memory is one other (non structuralist) variable, which is related to developmental stages. According to McLaughlin (1963), Pascual-Leone (1972), Case (1980 a) and Halford (1980) what limits pupils on the level of structure they can obtain in solving a problem is the amount of working memory available or the M-space. This is interpreted to mean that preoperational thinking would involve a constant (K)+1 item; early concrete, (K)+2, middle concrete, (K)+3; etc. A pupil with M-space of only (K)+2, would not be expected to solve problems demanding the simultaneous processing of (K)+3 items, unless the problem is presented in such a way that would legitimately be solved in a (K)+2 space. When this happens, as Case (1980 b) has demonstrated, the pupil at the 'early concrete' will have solved a middle concrete problem.

The educational implications of this concept of 'stage', is not that of 'wait-until-ready' strategy associated with Piaget. And so, 'stage' is not explained in terms of overall logical structures that exist in the mind of the pupil, but in terms of the amount of information that the individual can retain simultaneously, vis-à-vis the amount of information that the particular task requires for its solution. Decalages rather than present themselves as problems, merely show that some tasks present different information requirements to different pupils, depending on how much they already know about the task to be solved. An unfamiliar task will require more M-space than familiar ones. Given the fact that a pupil is required to handle different kinds of tasks at various development periods, development is conceptualised in this tradition, as an interaction between two processes, namely: (1) the increase in sophistication with which a child handles particular kinds of tasks within developmental stages which is indicative of a progressive increase in the amount of task relevant information that can be handled; (2) different developmental stages, which in themselves typify the nature of the task being attempted. In other words, by looking at the content of the task that is typically required by each Piagetian stage, as the pupil becomes increasingly familiar with each mode, the likelihood of handling complex problems within each mode increases.

Here, there is some similarity with Piaget's broad stage concept, but the mechanism within each stage is given a different interpretation.

2.8.2 STAGE AS UNIMPORTANT

This conception of stage-related phenomenon argues strongly, that development is essentially based on (or determined by) familiarity with the task in question (or task requirements). Stages, according to this tradition, do not explain development, but simply describe a state of organisation achieved so far Brainerd (1978). Stages as 'artefacts of measurement' imply that if (A) includes (B), then by successfully accomplishing (A), (B) will necessarily be accomplished. This view of stages suggests that the most important thing is to study the nature of the task, the strategies and skills involved and the prior knowledge required to solve it (Brainerd, 1978, Brown & Desforges, 1977, Smedslund,1977)

Perhaps a conception of stage which takes account of all the other conceptions, in view of the bulk of research evidence in support of 'stage-like' development, and the effect of environment and individual differences, would be more appropriate and comprehensive. (Fischer & Silvern, 1985)

2.9 FURTHER PRACTICAL DIFFICULTIES WITH PIAGET'S THEORY

Apart from the problems associated with Piaget's "stages", further limitations of his stage theory become apparent when one tries to answer two important questions raised by any developmentally based theory of instruction. These questions, as put forward by (Case (1978) are (1) how should we structure an educational environment so that the acquisition of the major system of intellectual operations can be optimised? The assumption here, is that the acquisition of these systems can be influenced by the sorts of environmental factors that are potentially under human control. A further assumption, is that the environment in which the child is currently being raised is not optimal from a developmental view point. (2) how should we design the instruction of valued facts and skills, such that they are geared to the system of knowledge-gathering operations that the learner has available? Once again, the assumption here being that instructions which are not geared to a pupils available system of operations will not be optimal. It is not uncommon that pupils distort the information which they reproduce moments after instruction, demonstration, and explanation, which is thought to utilise a more advanced level of thinking than they themselves employ. (Blatt and Kohlberg, 1971, Turiel, 1972)

The strategy which can be deployed to deal with these questions at the strategic level is obvious from Piaget's protocol. Firstly, one simply provides a detailed account of the way in which the major operational structures manifest themselves in the content areas which are important, eg., mathematics, science, and history. In other words, one undertakes a structural analysis of the content area. Secondly, one then determines the stage or level at which the students to be taught are presently functioning, i.e. determine the current operational thinking or functioning of the pupils. Thirdly, the curriculum is structured in such a way as to improve or promote the transition from one stage to another higher one.

This general procedure or steps for fostering operational development, and adapting instructional material to the current level of functioning of the pupils, is lucid. In order to transform these general steps into practice, Case (1978) suggests that a functional rather than a structural theory is required, due to the difficulties associated with each step. In fact, researchers, for example Biggs and Collis (1982) and Fusco (1983) who have worked within this area, have modified this general procedure because of the problems highlighted below.

Beginning with Step-1 which is concerned with structural analysis, Case (1978), illustrates the problems inherent in this step using conventional academic tasks. The best known Piagetian analysis of an operational structure which underlies the conservation of substance is taken as an example. In this instance, the specific concept to be learnt is that the amount of matter, water, plasticine, etc., in a container remains constant or unchanged (invariant) regardless of perceptual deformations. Only children who have acquired the concept will realise the invariability of the amount of matter. According to Piaget, they are able to do this because they have acquired the understanding that the increase in the salient dimension that occurs during the transformation is compensated for by a decrease in the less salient dimension. Symbolically, Piaget expresses this knowledge as $a1 * b1 = a2 * b2 = a3 * b3 =$ ------- where a and b are dimensions such as height and cross-sectional area, and where the subscript represent the different values which these dimensions may take. The pupil who can do this, according to Piaget, is capable of imagining increase in one dimension, and then reversing the result of this operation by imagining a decrease in the other. As reversibility is the characteristic of concrete operation, Piaget concludes that the knowledge underlying the concept conservation cannot be acquired, unless the child has acquired the system of concrete operations.

This analysis is quite appropriate for Piaget's purposes. However, in extending it to classroom task, it becomes problematic. Case (1978, p.172) seems to think that the groupings of logical operations described above may not have any role in other areas of academic study, except in science and mathematics. Furthermore, Piaget did not disclose the procedure which he used to uncover the role of the above logical grouping; for instance, watching the pupils' actual performance during conservation task does not give any indication that they are making mental compensation of the difference in height and in the cross-sectional area. One possible conclusion which can be drawn from this is that the procedure for determining the underlying operational structure is not simply to analyse pupils' responses to the task. Perhaps, it must be to analyse, instead, the knowledge that this performance was presumed to imply. Case (1978) maintains that it is still not quite clear how the operational structures that underlie specific tasks should be identified, even in well-defined areas requiring logical reasoning, such as mathematics and science.

Nevertheless, if in analysing pupils' responses in order to determine the underlying operational structures, the knowledge implied by their performance is what is being analysed, then, it may be that identifying and analysing this knowledge in terms of Bloom's protocols can be helpful. And it is quite possible to relate such analysis to Piagetian protocol and the structure of observed learning outcome, identified by Biggs and Collis (1982). Fusco (1983), tried this idea in literature as a subject for secondary school pupils.

Indeed Biggs and Collis (1982) and Shayer and Adey (1981) think that the operational structure underlying a particular curriculum subject can be identified. Biggs and Collis (1982) argue that such determination would involve a number of experts in the subject area in question, psychologist and educators, sitting together to discuss these underlying operational constructs. They would have to look at the aims of the subjects, etc., and the sort of activity which the pupils are required to carry out. They also give instances of this procedure in other areas of the curriculum. Shayer and Adey (1981) suggest that by reading the objectives of a course it is quite easy to elicit the underlying operational structures - what they have described as abstract descriptors - of the course. These appear to be the things that one expert in the subject area in question values, which another would readily agree as being important for understanding or operating effectively within the course or subject.

In Step-2, which is concerned with the assessment of pupils' current level of thinking, Piagetian protocol suggests batteries of Piagetian tests, which can simply be administered, and pupils' level of operation (thinking) determined using appropriate scales. This looks simple, but it is not as simple as it looks, according to Case (1978). Because when the items on Piagetian tests which presumably tap very similar structure, are correlated, the coefficients are usually low and sometimes insignificant. However, it is quite common for two tests of the same mental battery to show low correlation coefficients. What this suggests from the point of view of instruction is that pupils', level of functioning must be assessed with regard to the specific structure that is required for a given task. (Case, 1978, p.173) Granted that the low correlation of these tests items (of related structures) results, because of uncontrolled test factors, according to (Case 1978),

> it would not be possible to know whether a given child's performance resulted from the presence or absence of a particular operational structure of interest or from a response to one of the uncontrolled task factors. (p.173)

More serious problems arise when Piagetian tests are used for ascertaining the level of pupils' thinking. This problem, is that of 'decalage' among tasks of supposed identically underlying structure. The absolute level of success varies widely, depending on the particular test item employed. For example, number conservation test is taken at age six years, whilst weight and displaced volume conservation tests are not taken until about the age of nine or ten years and eleven years respectively. This represents a serious problem from an educational viewpoint. If we are led to assume that a given structure is present at the kindergarten age, but may not be used or applied to a certain task until high school age, then the chances of knowing whether or not a pupil has acquired the structure are very small. Except through applying the structure to tasks that is of instructional relevance. But Piaget has not specified in his theory the factors that affect the application of intellectual structure to specific tasks.

Step-3, having got the structural analysis of the subject and the operational level of functioning, the teaching of curriculum materials has to be adapted so that the pupils may work within their current level of functioning throughout each curriculum unit. However, in planning instruction so that it matches with pupils' existing structures, there are problems in optimising pupils' application of existing structures to new content areas. This is so, particularly as Piaget's theory concerns only the process of structural knowledge acquisition, and ignores the process of structural application. And very little guidance is obtained therefrom. It may be that the task factors responsible for affecting structural application may turn out to be identical to those responsible for structural knowledge acquisition.

CHAPTER - 3

3.1 FUNCTIONAL THEORY (An Alternative/Complement to Piaget)

A case for functional theory has been put forward by Case (1978). Although it is still in its infancy, it is worthy of consideration because of its potential. Acknowledging that the problems highlighted above do not disqualify Piaget's theory completely, Case (1978) intimates, that they are (serious as they are) traceable to a common source: namely, that Piaget's theory is predominantly structural rather than functional. As mentioned earlier, Piaget's concern has been to provide a logical description of the systems of intellectual operations which children possess at various levels in their development, rather than provide a psychological description of the processes by which these operations are acquired and utilised. (Flavell and Wohlwill, 1969)

The desirability of a functional rather than structural theory of development has been stressed by Case (1978), if we are to describe the processes by which these operations are acquired and utilised, thus reducing some of the problems or difficulties associated with Piaget's theory mentioned above. As a "supplement" or alternative to Piaget's theory, such functional theory of intellectual development promises to facilitate the development of operative structure, by identifying the intellectual operations relevant to various academic disciplines more easily. This is so, according to Case (1975) because these intellectual operations will be induced more directly from children's actual performance, thus reducing the dependence on abstract logical analysis. Furthermore, with functional theory, the pupil's current level of functioning can be easily assessed, because the factors which constrain performance are better understood, and the assessment is one which is more closely related to observed performance. Also, adapting materials or methods of instructions to the operational level of the pupils will be facilitated by a functional theory, because the materials or methods will be easily analysed in terms of their developmental appropriateness. So, too, will the assessment of student characteristics which will determine their ability to benefit from one method or another, be made easier, because there will be a better understanding of the internal variables that determine pupil's reaction to task factors. Furthermore, with a functional theory, it would be easier to arrange the sequence of activities which would optimise the application of already existing structures to new conceptual domains; because the theory would specify the performance factors which are of great relevance not only to the process of acquisition, but also to the process of structural application (if indeed they are different) (Case 1978, p.178)

The functional theory suggested above by Case takes into account Piaget's developmental theory. This theory is rooted in Pascual Leone's idea (1969). It is attractive as a theory, because it attempts to provide a more detailed account of the functional factors which influenced the acquisition and application of specific Piagetian structures.

3.2 SOME ASSUMPTIONS MADE BY FUNCTION THEORY

This theory assumes that all human knowledge, be it factual or procedural, is stored in the psychological system, via entities called schemes. Just like units of knowledge, schemes are thought to consist of two components: namely, (1) an initial set of conditions under which they apply (releasing component); (2) a subsequent set of conditions they generate, (their effecting component). For instance, a five year old's capacity to solve a conservation task, i.e.., comparing two beakers and judging that they contain an equal amount of water, interpreted in these terms: it is assumed that he has this capacity because he already possesses a scheme for equality in his cognitive repertoire. The particular meaning which he attaches to equality at his particular stage of development constitutes the effecting component of this scheme. The releasing component, is the set of possible conditions under which he may legitimately assign this meaning. Schemes perform a number of functions such as representational function i.e.., representing facts, states, or meanings, (figurative), transformational function, i.e.., operating on one set of figurative schemes to generate as products a new figurative scheme or set of schemes (operative schemes), control function, i.e.., monitoring the series of operations a subject intends to execute in order to get from one figurative state to another, (executive).

The general idea of the functional theory is reflected through a detail and functional analysis of conservation of liquid substance task. In solving such tasks, pupils appear to go through certain stages, namely,

(1) Uni-dimensional Scanning

(2) Bi-dimensional Scanning

(3) Reasoning in terms of initial state

The sequence of structure which Piaget has described is regarded as a series of executive schemes in Pascual-Leone's functional theory. In the case of the conservation task example, the executive schemes which are of relevance to this task have to do with the evaluation of quantity. The pupils begin by evaluating quantity unidimensionally, i.e. by relying on, say, height alone. When they perceive that this does not work, they look for a basis for improving their evaluations. They may use width and height alternatively, then both jointly. This bi-dimensional executive basis of evaluation becomes inadequate for situations where compensation, comparison of height and width are apparent. Again, when pupils find difficulties or perceive contradictions, in the comparison, they search for a better basis for quantification.

However, details about this model which can be seen in Case (1978) are speculative and as yet untested widely. From the examples which he presents, the important thing is not just the specific set of mental steps or schemes which have been postulated but the set of performance factors which emerge when this sort of approach to modelling children's development is adopted. These factors include:

(1) the rate at which a pupil is capable of attending to several schemes at once (M-power);

(2) the pupil's attraction or resistance to the influence of perceptual set;

(3) past or previous experience;

(4) the pupil's affective disposition.

These four factors frequently appear as underlying successful or unsuccessful acquisition, and form the basis of a general theory of the process by which children acquire and apply the cognitive structures which Pascual-Leone has constructed. For a complete presentation of the theory, see Pascual-Leone (1970, 1972, 1976).

3.3 HOW THE FUNCTIONAL THEORY DEALS WITH SOME OF THE QUESTIONS RAISED BY PIAGET'S THEORY

3.3.1 ENSURING THE DEVELOPMENT OF OPERATIONAL STRUCTURE:

Where the question is one of ensuring the development of operational structure, under Piagetian protocol, it is difficult to undertake a structural analysis for reasons already given. Namely, (1) The logical nature of the structure to be analysed and its irrelevance in some conventional academic areas. (2) The nature of the analysis to be carried out on the structures is competence analysis, instead of performance analysis (i.e. ability and attainment). In any event, students' performance is an unreliable and uncertain guide to their competence. Piaget, however, did not suggest any general method for proceeding from one to the other. Nevertheless, in the context of functional theory, the structure to be analysed, is an executive not a logical one. The significance of the executive structure is obvious in most academic disciplines. Indeed,

> since the function of an executive structure is precisely to control subject's performance in a given task domain, the nature of the structure that is required to execute a given task may be inferred directly from the performance of skilled subjects on that task. (Case, 1978, p.205).

The steps which may be followed in order to carry out executive analysis of a task are as follows:-

3.3.2 STRUCTURAL ANALYSIS

(1) Identify the goal of the task (sample of technological task) to be performed. (This can be done looking at the questions pupils are asked to answer.)

(2) Map out a series of steps by which successful subjects might reach this goal. {One way of doing this is to execute the criterion task yourself, and list the sequence of operations which you underwent in order to reach the goal. This might involve mapping out your general sequence of steps; then perhaps the sequence of suboperations you executed within each of these general steps.}

(3) Then compare these hypothetical steps in (2) with the actual performance exhibited by the subjects. For example, you can note the sequence of motor movements that experienced subjects exhibit as they evaluate the task. (O'Bryan and Boersma, 1971). Alternatively, you could interview a skilled performer. Ask him or her to describe how he or she actually proceeded through the task and what he/she was thinking as he/she did so.

(4) Make changes if necessary, otherwise make sure that the hypothesised steps correspond to those used by skilled performers.

In some important respects, the procedure for analysing (or determining) the underlying structure of a task as outlined by Case is similar to that outlined by Shayer and Adey (1981), and Biggs and Collis (1982). The latter's represents a conceptual shift in their position regarding the notion of logical structure which underlie pupils' performance. In order to carry out an adequate analysis of a task, so as to determine the process skills or

> "abstract descriptors" (Shayer and Adey, 1981), or "genetic code" (Bruner, 1960), (Biggs and Collis, 1982),

ideally a team of specialists in the area, curriculum experts, and psychologists, will be required. The first stage in this comprehensive assault on the curriculum would necessitate searching among the curriculum objectives for certain underlying principles of analysis. This invariably involves a consideration of the nature and purpose of studying the technology curriculum.

3.3.3 ASSESSMENT OF PUPILS' CURRENT LEVEL OF FUNCTIONING

The difficulty in assessing pupils' current level of functioning is accounted for partly by the presence of uncontrolled performance factors. The reported low intercorrelations among tasks which are supposed to tap closely related underlying structures, and the presence of decalages between tasks, point to the existence of these uncontrolled factors. Due to these two phenomena, it is difficult to say whether a given test result is a function of the presence or absence of an underlying logical structure or from the individual's success or failure in coping with one of the unidentified performance factors involved in the task. (Case, 1978)

The factors inherent in most Piagetian tasks have been identified with sufficient accuracy by this alternative system. It suggests that pupils' failure to utilise a given executive structure (Logical Structures in Piagetian protocol), would be due to any of the following factors:-

(1) Insufficient M-space (memory space)

(2) Sensitivity to the perceptual cues involved (field independence)

(3) Lack of task relevant experience (the average of (1) and (2) above.

In Case's theory, the nature of relevant operational structure is redefined. And the reason for using inadequate executive structure in a particular context is not important. Of importance, is what executive structure the pupil actually uses. The method of assessing the pupil's current level of functioning is the same as in structural analysis. But the strategy that leads to an incorrect rather than a correct answer is what has to be assessed, especially as the entity to be assessed is executive strategy in the task. In practice, however, this is much more difficult, because we use correct strategy and we may find it difficult to imagine ourselves in the pupils' positions and mentally come up with a strategy which lead to their answer. Furthermore, because of the inarticulateness of students who failed compared with those who passed, information about their thought processes may be more difficult to get. Due to the problems involved in analysing incorrect strategy vis-à-vis the correct one, it is helpful to convert an incorrect strategy into a correct one. This can be carried out in two possible ways:-

(1) by determining the question for which the response would have been correct. Make this question a goal, then go through steps (2) to (4) of the structural analysis.

(2) assume that the pupils' have no access to some crucial piece of information which they appear to ignore to do a task. Present this task to mature students without this information. Hypothesise the procedure for solving the task. Compare this with the actual procedure used.

3.3.4 ADAPTING THE CONTENT OF INSTRUCTION TO THE OPERATIONAL LEVEL OF THE LEARNER (MATCHING)

Where the question is about adapting the content of instruction to the operational level of the learner, (matching), the steps already mentioned apply. Initially, adopting the content of instruction to the operational level of the learner means:

(1) modifying the tasks presented to the pupils so that they do not have to use a higher level of operative functioning than that which they have already developed;.

(2) giving pupils tasks which would normally require a higher level of operative functioning, but teaching them some trick or special procedures for solving it. In this respect, certain formal tasks can be solved using concrete operation. {Teaching simple strategies to solve complex tasks.}

However, the same phrase has three meanings within the alternative framework, due to the fact that the operative level of the child may be defined either in terms of the strategies he currently deploys, or the M-level he has reached. In addition to the two Piagetian meanings, it can have the third meaning which is teaching complex strategies for solving complex problems, but doing this in such a way that the subjective complexity of the learning sequence never exceeds the subjects' available M-space. (Case, 1978, p.212). No matter which of these meanings is used, the procedure for adapting the content to the operational level of the learner is similar. These definitions are merely underlining the important point, that teaching and pupils' conceptual level have to be integrated, if a "reasonable" demand is to be made on the pupils. In other words, the issue here is pedagogical not curricular. The teacher may pitch the instruction material to be learnt at a level higher (or lower) than the students' thinking. It is not that the material has thinking higher than that of the students.

3.4 THIS THESIS' APPROACH TO DESCRIBING PUPILS' TECHNOLOGICAL THINKING

Piaget was the first to undertake a relatively detailed description of pupils' thinking. Yet, as is apparent from the exposition of his work (theory etc.,) fundamental difficulties have been detected, particularly with regards to his concepts of "stage", "equilibration", etc. Consequently, it has been questionable to organise educational programmes, for instance, developmentally based instructions, around Piaget's ideas. However, the existence of two "systems", is implied in the assertion by Case (1985) that when the characteristics of a task have been specified, the observed thinking of the pupils cannot be described in logico-mathematical terminology of Piaget, but in terms of Executive Control Structures (ECS). Piaget himself appears to have recognised that there are two "systems" as he makes the distinction between logical structure and performance (Vuyk, 1981), but accordingly ignores what may be termed the strategies of the thinker. There is some truth in this statement.

Undoubtedly, every system for describing something that exists is limited, and so Piaget's scheme is limited. However, the real question in this regard is: does each system actually provide any insight into pupils' thinking? It seems to me that it is a question of how close one wants to get into a phenomenon. For instance, if I take myself as thinking at this moment, then one way of describing me can be a Piagetian way. I am presumably obeying certain rules of logic, because I am not contradicting or trying to contradict myself. I am thinking in a formal operational way.

Certainly, that may be telling part of the story, because another way of looking at, or describing my thinking, can be perhaps the sort of description put forward by Case, and the others which has to do with matters of production, execution etc., more directly than Piaget's scheme. Piaget's scheme refers to the kind of general framework that I might use. Although he describes this general framework quite well, he has not, or may not have, described the actual production or execution of thoughts to a finished conclusion, because there are other kinds of descriptions. In view of the limitations associated with Piaget as outlined above, and of the fact that he is not specific enough about technological skills, it may be concluded that his approach based on meta-theoretical explanation is not appropriate for this thesis, and will not be used. An approach which involves looking not at pupils and the curriculum separately, but looking at pupils as they solve technology problems.(i.e.. Piaget's 2-tier) is my favourite.

In other words, instead of just getting a group of pupils and giving them Piagetian tests, and then having the syllabus analysed using the same framework, we need to observe pupils actually thinking about technological problems, if a description of the way in which they are thinking is to be undertaken. This can be a difficult task, but it has been forced upon me by the logic of my argument. However, this makes sense, because if the pupils class test scores are taken, then the process skills which they have used in solving the problem, (which is what this investigation is all about) will be difficult to describe or determine.

This will allow me to approach the problem of how to elicit or describe pupils' technological thinking confidently and/or differently, because it will enable me to look at the pupils' actual technological work to see the kind of steps they seem to be going through. This approach cannot be limited, because one cannot see, literally, what is going on in the pupils' minds. It is likely to provide an insight into the way pupils are actually thinking in technology. As a first step forward using this approach, it is necessary to have a thorough understanding about the concept of technology, and how it is being taught in schools.

SECTION - THREE ~ LITERATURE REVIEW (PART 2)

RELATED LITERATURE REVIEW PART-2

CHAPTER - 4

DESIGN & TECHNOLOGY - ITS MEANING FOR EDUCATION TODAY

4.1 THE NATURE OF DESIGN AND TECHNOLOGY

Having identified and examined the psychological principles/protocols which exist within Cognitive Psychology for tackling the problem under investigation, attention will now be focused on the subject of design and technology itself. In early 1980, it became apparent that the traditional technology was to be relaunched anew as Design & Technology. As from mid-1985, when the new subject of Design & Technology became one of the National Curriculum subjects, the bulk of the research/investigation work concentrated on the nature of, justification for, and general curriculum development etc. within the subject. Research work that examines the relationship between the cognitive development of the pupils and the sort of demands being made upon them by design and technology subject, has been sparse in a neglected area.

It is generally felt that it is not a good idea to design a Design & Technology curriculum without first acquiring a deep understanding of the ways in which children and young people think about design and technology. Here lies a real potential for all sorts of problems with learning and teaching design and technology, as indicated by McCormick (1995). In spite of these potential problems, the most important skill for the future, according to Johnson (1992), is the ability to think.

These few research papers will be looked at first, then attention will be turned to other related areas of design and technology where there has been a great deal of research work.

The first known published research which attempted to relate the psychological characteristics of the pupils to the demands of a technological curriculum was Oboho & Bolton (1989) at the International Conference for DATA at Loughborough University of Technology.

In a revised edition of their work, Oboho & Bolton (1992) using a typical Piagetian protocol, analysed the ability to think in the design and technology subject area from a sample of 50 pupils aged 11-16 years in a comprehensive school. Although attempts were made to define technological thinking and outline insight gained about how it developed, no detailed description of a taxonomy of the different schemata required for understanding design and technology was produced.

In a longitudinal study of key stage (KS) 1 & 2 pupils, Roden (1997), attempted to identify and classify consequently developing, and changing problem-solving strategies in design and technology. Children were closely observed from reception to Yr. 2 as they were engaged in six different design and technology tasks which were analysed using systemic network (Bliss et.al., 1983) and open coding technique (Strauss, 1987). This was in an attempt to develop a taxonomy of young children's problem-solving strategies within the psychological development framework which particularly acknowledges the notion of co-operation in problem-solving, which is essential in design and technology enterprise. This psychological framework is 'situated cognition', which according to Lave (1992) offers a view of cognitive process that differed according to the domain of thinking and the specifics of the task and context. This valued the ultimate connection between knowing and doing and viewed learning as a process of enculturation through shared activities into a community of practice.

The following categories, not in any order of importance, were identified, namely:

(a) Personalization - pupils relate tasks to their experience

(b) Practice - pupils manipulate test

(c) Identification of needs - pupils relate resources to task

(d) Negotiation and reposing the task - pupils able to explore task boundary

(e) Focusing down - pupils interpret and explain tasks to themselves.

(f) Identifying difficulties - pupils able to pinpoint problem

(g) Talking themselves through sub-tasks - egocentric speech

(h) Tackling obstacles - pupils seek help

(i) Sharing and co-operating - pupils give advice and assistance with orwithout being asked. They ask detailed questions concerning procedures.

(j) Praise, encouragement and seeking reassurance - pupils support each other and gain confidence.

Certainly, these categories need to be processed properly so that they can become part of the wider categories which have been or are yet to be identified.

In his description of a model for problem-solving involving electronics, Martin (1990), in somewhat general terms, outlined the stages in systems thinking used by pupils aged 5 - 16. This albeit ad hoc model, involved thinking in terms of (or progression from) systems, through subsystems to components. No attempt was made to identify and describe the 'generic code'/ 'abstract descriptors' involved in such 'system thinking'. For each stage in Martin's (1990) system thinking, the activities expected of pupils are suggested, as follows:

(1) System Stage, the activities involve exploring, specifying system, selecting sub-system, testing system and appraising system.

(2) Sub-system Stage, the activities involve selecting subsystem, integrating, testing sub-systems.

(3) Components Stage, the activities involve selecting components, building sub-systems and designing PCBs.

In considering the cognitive style related to design process, Pearson (1991) went further by examining the thinking process underlying one major feature of a design process i.e. the generation of ideas, and the development of one of them, (or integration of several ideas). Using a revised version of Witkin's Group Embedded Figure Test (GEFT) and two further tests of a similar type, he reported that the field dependence/independence measured by these tests may be an important factor in relation to the ability to design. It is worth remembering that the idea of cognitive style of field dependence/independence takes into account the surrounding influences or stimulus field, which form an integral part of the problem given. If one controls these surrounding influences to a given problem, then one can apply this in turn to help others solve problems more efficiently in design and technology as well as other subjects. The degree of help required by an individual would depend on his position on a field dependent/independent continuum measured by his ability to manipulate shapes in an embedded test.

By advocating the ability to think as the most important skill for the future, Johnson (1992) proposed five dimensions of thinking which could be used as the focus for an intellectual process curriculum within the framework of design and technology education. These were, viz:

1. thinking processes
2. core thinking skills
3. critical and creative thinking
4. meta-cognition; and
5. the relationship of content to thinking.

Within the framework for developing intellectual process curriculum, the correlation of each of the dimensions was for

(i) identifying goals;

(ii) developing an instructional model;

(iii) building a five instructional principles for developing intellectual process.

a) helping students organise their knowledge;

b) building on what they already know;

c) facilitating information processing;

d) facilitating deep thinking

e) making thinking processes explicit

iv) enhancing the role of the teacher as a facilitator

v) developing an evaluation process.

Although narrowing the curriculum was a weakness in Johnson's idea (1992), it is not clear how educationally or scientifically important it is. There was also an apparent neglect of context knowledge. In his in-depth treatment of the cognitive context of technology, Vincent (1990) identified the highly systematic, analytical process involved in the development of flush riveting systems in the aircraft industry. If anything, Vincent (1990) has pointed out that a vast body of cognitive content exists and must be appropriately identified as technological knowledge.

Custer (1994) asserted that because technological activity is, by definition, a human activity, the dimensions of human cognitive style characteristics must be incorporated into the problem-solving structure. Thus the inventive process was described as a function of divergent thinking and creativity. The trouble-shooting process generally required convergent thinking and an application of established procedures.

It is clear from the few research contributions reviewed that no serious attempts have been made to develop a taxonomy of schema in design and technology which could help to organise the teaching of concepts, theories, procedures and tasks. In order to develop such taxonomy, the requirements would include:

(1) an understanding of- and reflection on- the work of Piaget in science and other areas of the curriculum, as in previous sections;

(2) a very delicate deployment of Bloom and Solo's taxonomies;

(3) analysis of design and technology curriculum at KS 3 &4; and

(4) analysis of pupils responses from design and technology tasks.

Before proceeding further on this we need to review the work in the other areas of design and technology curriculum, concerned with the nature, justification, development and organisation of design and technology within the school system. The significance of this part of the review was conjoined with the psychological review section to produce a design and technology taxonomy shown in the taxonomy section.

Section two on psychology has portrayed Piaget as a rationalist but it has been shown that there is more empiricism to Piaget's work than rationalism. However, modern views about technology are empirical in character, as will be demonstrated here, in the course of historical development.

In this section an attempt will be made to examine the nature of technology and how it has been conceptualised in the National Curriculum and in schools. From such examinations, it is also hoped that a guide to designing or choosing appropriate technology tests will emerge.

It must be said, however, that a clear and unequivocal definition of the concept of design and technology is problematic. Problematic, because historical and systematic analyses carried out so far shows that the concept is of a highly generalised character and/or has a lot of forms, and that it interact with our lives in a number of ways (Laudan, 1984, p.1; DeBono, 1971). The result, has been differing versions of the concept and disagreements on a precise definition (Skolimowski, 1968); (Tondl, 1974); (Rapp, 1981). Given that the concept of technology has manifold determinants, it is quite unreasonable to expect a universally agreed definition of technology. But to do without one at all, is a mistake. The definition of technology, which is intended to be adopted here, will be one that reflects the present-day usage of the concept because during the course of historical development, different forms of technology have occurred (Rapp, 1981, p.31). Accordingly, design and technology has been defined in the National Curriculum document as a capability (to or for) combining design and making skills with knowledge and understanding, in order to design and make products. (DFEE 1995).

This definition must, of necessity, have some foundation. What is the basis for this definition? It is important to understand this, if there is to be an appreciation of how it operates the way it does, in schools.
In this attempt, the term design and technology, although used as one in the singular in the National Curriculum document, has been separated, for good reasons of understanding and clarity, by (Eggleston, 1996) into two, namely: design as one element and technology as the other. Acknowledging a close relationship between them, Eggleston states that design

> consists of using technology to achieve solutions that satisfy design criteria. Technology by the same token, consists of using design to achieve solutions that satisfy technological criteria. (p.24)

This relationship is not well brought out by Eggleston. For there to be a relationship, there must be a third or mediating factor or variable. The conceptual framework for establishing this will be explored later. The technology component would be examined in detail, followed by the design component.

If pupils' technological thinking is to be matched with a technological curriculum, then technology has to be seen in its original form and in its consequential ramifications: i.e., in its abstract and material forms. In other words, a general analysis of technology will be attempted which will provide guidelines for determining the sorts of thinking, structure, concepts and skills involved. The basis of such analysis has to be a frame of mind that permits us to go beyond the normally conceived instrumental function of technology subjects. This is an indication that technology can be understood in two essential ways.

4.2 A CONCEPTUAL FRAMEWORK FOR UNDERSTANDING TECHNOLOGY

According to Rapp (1974), it is common for people to conceive or understand the instrumental function of technology, like the technical operations used in modern engineering, in practical terms, designed to direct the natural forces according to human purposes. However, beyond the realm of mere practical skills of which technology is normally conceived, it is not difficult to realise that before an intended useful technological product or result or object is achieved,

> a planned and preconceived action processes, involving the deliberately considered application of well designed tools and devices must take place. (Rapp, 1974, p.vii).

In other words, theoretical reasoning is a necessary condition for the accomplishment of pragmatic technological aims.

Although, presently technology is indeed a very complex subject matter, because its product involves a process of social action, it can be analysed from different points of view, grouped roughly, into two approaches. The first group of approaches focuses attention on the logical and methodological structure of:-

(a) the action processes performed;

(b) the knowledge applied within them;

(c) the objects subsequently realised.

This approach is appropriate for investigation in the field of engineering, systems analysis and management, because it is pragmatic in nature and designed to arrive at more efficient methods, in planning, design and implementation as well as research and development processes. It can also be clearly associated with the philosophy of technology. Although this approach is devoid of human elements, it is concerned with the general methodology, and theory of knowledge.

The focus of the second group of approach, is on the people involved in the action process. This constitutes the social dimension of technology, which involves giving an adequate account of the sources of technological change and evaluating its impact on human society. This second group of approaches, falls in the broad area of technological philosophy, i.e. social and cultural philosophy.

However, with reference to the first approach above with which this thesis is in sympathy, it cannot be said that the above-mentioned categories are necessarily good or appropriate, because each can be treated under different headings. For example, (a) above i.e., the analysis of the action processes performed, can be regarded as belonging to the general methodology of social action. Whereas (b) above, i.e., the formation and structure of technological knowledge and its theoretical formulation may be treated as part of the established philosophy of science, (c), i.e., the investigation of the production process and the structure of technical objects, can be considered under the heading of systems engineering and cybernetics.

The treatment of each under different headings is not without problems. And the fact that the various branches of technology exhibit differences in procedure and in the level of their theoretical elaboration, demands that the philosophy of technology unifies the conceptual structure of the common traits of the various issues. Hence, its attraction. Now let us examine how technology is understood within the identified framework with which this thesis identifies.

4.3 THE CONCEPT OF TECHNOLOGY - A NARROW VIEW

4.3.1 TECHNOLOGY AS SKILLS

Technology can be understood in a narrow sense as skills of technique (certain procedures, learnable skills such as the technique of driving a car, playing a piano etc.) This understanding of technology as skills, understandably, originates from the meaning which the Greeks attach to the word technology, namely, "techne" (art or skills, or method of making something).

Thus, operating skills has been a central concept in people's idea of technology. Feibleman (1966) has taken on board this idea and begins his conception of technology by attempting an analysis of it and its related concepts. This he does by making a distinction between technology and pure science, as well as applied science. One probable reason and basis for such a distinction is the alleged relationship between both and the ends pursued by each, respectively. Pure science, he claims, aims at knowledge and consists of theoretical constructs arranged toward knowing. Whereas, applied science aims at practice. Moreover, applied science is thought to have, in addition, the concrete application of such theory. In other words, there is a theory of operating (theory of practice) and an actual way of operating (concrete application of this theory). This actual way of operating is regarded as technology. Or more directly, technology is skills. Feibleman (1966), illustrates this using the example of a space programme (and indeed any similar programme for that matter), showing how this conception of technology may be incorporated into a common-sense view of modern technology. Accordingly, the normal steps will be:

(1) acquiring strictly scientific knowledge about the general laws of nature: e.g., gravitation, etc., concrete formation about the world, e.g., moon orbits the earth (science);

(2) with (1) as the basis, a practical theory on how to go to the moon is devised: e.g., involving ascertaining rocket size, trajectories or space ship etc. (applied science);

(3) the actual construction of the hardware (technology);

Thus, according to Feibleman (1966),

> "an activity which immediately produces artefacts",

is technology. This obviously sets the scene for further probing because he is silent about the nature or structure of this activity.

However, it is inadequate philosophically to regard technology as skills or techniques or even skills for making. This is not difficult to pinpoint. Mitcham and Mackay (1972) intimate that not only are there techniques for acting plus those for making; there are, as well, different making skills other than those associated with technology, for example, artistic skills. Specifically Mitcham and Mackay (1972) think that Feibleman (1966) has not clearly and conceptually distinguished between techniques of acting and skills of making. The description of technology as skills merely refers to the making of objects by crafts or art skills, devoid of any theoretical basis. Later, the philosophical foundation of this narrow view of technology will be examined. Now, attention will be focused on a "broader" view of technology.

4.4 CONCEPTION OF TECHNOLOGY - (BROADER VIEW)

4.4.1 TECHNOLOGY AS KNOWLEDGE

However, going beyond Fiebleman (1966), the search through the relevant literature reveals, that a philosophically adequate conception of technology, requires three complementary approaches, namely, epistemological, anthropological and sociological.

Briefly, an epistemological approach attempts to put technology within the scope of human knowledge, and evaluates technology as a form of human knowledge. The contribution of the anthropological approach is in its attempt to relate technology to the nature of man. From this approach, all forms of knowledge take on a technological character. The sociological approach sees technology as the defining characteristic of thought and action.

A detailed treatment of each approach will not be attempted here because, apart from the fact that each approach stresses points which the others ignore, thus helping us to comprehend technology fully, interestingly, they have one important theme in common; which is, their reference to, or treatment of, technology as knowledge. This definition, is further supported by metaphysical studies of technology by Heidegger, Dessauer, Jonas, wherein knowledge is seen either as precondition or as product. Lawton (1979, p.4) has concurred that technology can be regarded as

'---- a kind of knowledge.'

McGraw-Hill Encyclopaedia of Science and Technology, 5th edition, refers to technology, as "systematic knowledge and action".

The suggestion here is that despite conceptual problems surrounding the definition of the concept of technology, and despite a lack of unanimity about the appropriate way to approach technology, it is proper to approach it, at least initially, from the epistemological point of view, although this can hardly be pursued independently of anthropological and sociological considerations.

These latter approaches will not be considered in this work, except perhaps those aspects that may be relevant to an epistemological approach.

The advantage of the epistemological approach is associated with its capability to study the structure, conditions, and validity of human knowledge. It also has the capability of relating technology to other forms of human knowledge, especially science. These features of epistemology promise to facilitate the sort of analysis to which technology will be subjected later on in this work.

4.5 WHAT KIND OF KNOWLEDGE IS TECHNOLOGY?

4.5.1 WHAT IS KNOWLEDGE?

The elusiveness in the search for knowledge, is indicative of how uncertain we are about what knowledge is. The difficulty of defining what knowledge is has confronted the epistemologists for centuries, and the mystery surrounding knowledge has intrigued humanity. Although ancient Greek philosophers such as, and including the sophists, the Ionic school, Socrates, Plato and Aristotle, struggled to arrive at a concise and universal definition of knowledge, knowledge continues to be a word commonly used nowadays, but probably not understood.

In his attempt at defining knowledge, Hamlyn (1970), tells us what knowledge is not. For example, it is not faith, it is not belief and it is not reason. Yet it can be said that knowledge does something to us that brings about change, and we can use knowledge to accomplish a desired end. These words appear to have added to our confusion about the nature of knowledge because they sometimes suggest a kind of knowledge that transcends the normal mental processes: i.e., a knowledge that is 'supernatural' in its origin, and sometimes, the words suggest a kind of substitute for knowledge. And yet at another time, they suggest nothing more than a concatenation of thoughts, i.e., a chain of related ideas. They provide elements of knowledge.

Nevertheless, faith, belief, and reason each make a fundamental contribution to that which is accepted as true knowledge. The contribution of FAITH is its assumption of authority: That of BELIEF, is its substitution of plausibility in the absence of fact. And the contribution of REASON is a system for the systematic arrangement of ideas so as to give them a semblance of reality to the mind, and therefore an inclination to accept them as being true knowledge.

It is worth examining each one of these elements, briefly, by drawing from and sharing the opinion expressed in (Rosicrucian Digest, 1987).

4.5.1(a) Faith

According to this digest, by keeping aside the conventional dictionary definition of the word faith, it will be possible to arrive at a better understanding of it from common usage. Most people talk about faith as if it is an immediate and direct experience, and therefore has the value of knowledge. However, faith and experience are not interchangeable in meaning. The latter comes through the medium of our five objective faculties or senses, and it is direct and immediate. There is no intermediary between us and the impressions from the object(s) which we perceive. It is not inconceivable, that the essence of knowledge must be the same. Thus, no matter what the ideas are which knowledge is composed of, its essence, i.e., the quality which knowledge consists of, must always be the same. This quality of true knowledge is REALITY. This reality must and (should be) that which we or others can experience or perceive (i.e., be seen, felt, heard, etc.) as reality. This is not to imply that what we learn by study is true knowledge, because we may never be able personally to perceive as reality what we read in a text book, or in history books. Yet the contents of such text books is regarded as KNOWLEDGE: (a socially accepted substitute for our own intimate acquired knowledge.)

However, when one is described as an authority, what is normally implied, is that one has closely and objectively experienced what he relates, or has reason to believe, such reality as demonstrable. The difference between faith and socially acceptable knowledge, referred to above becomes apparent, whereas, in faith we accept as an authoritative source, that which cannot be universally substantiated, in socially acceptable knowledge, the authority can and will substantiate what he has expounded. In faith, because the source of authority is thought to be infallible, 'supernatural', the belief sets in, and it becomes sacrilegious to question the substance of faith. Certainly, its content is now knowledge in the realistic objective sense.

4.5.1(b) Belief

Belief can be classified into universal belief and personal. Universal belief implies that an idea or concept which has widespread currency, and is thought to be irrefutable. Because a number of persons have a similar belief, it, psychologically speaking, becomes truth. That in which we believe may be false, and it has happened on several occasions. Refuting that which is universally accepted idea which proved to be wrong, takes courage and time. Personal belief is not influenced by the opinions of others. This belief may be arrived at by one's own mental processes, rather than by internal reasoning. A typical instance would be an occasion where one's attention is called to some event, a happening, or a phenomenon, which no conclusive explanation has been given. One then thinks about this, by associating ideas without using any method of formal reasoning, and arrives at a personal conviction as to the cause of the phenomenon. The individual in question here may have recalled from his memory various associated ideas, which have assisted in providing a plausible personal conviction for his belief. We cannot refer to such beliefs which have neither been proven or refuted, as knowledge. 'Intuitive' knowledge, is one type of personal conviction. Nevertheless, intuitive impressions, which flash into one's consciousness effortlessly, do have indubitable truthfulness (or veracity). These intuitive impressions derive the substance of true knowledge, because of the clarity of their illumination to the person receiving them. Most of the times, these intuitive impressions cannot be reduced to factual substance. The individual involved may be unable to prove his beliefs to another person. And others may be unable to disprove it. Thus, intuitive impression, or this form of subjective knowledge, lacks the objectivity of reality, and thus, is only of immediate benefit to the one having the intuitive illumination. He is then obliged to give substance to his intuitive knowledge: i.e., to try to give it that reality which can be perceived by others, so that it can become universal knowledge. The method by which this is accomplished is reason.

4.5.1(c) Reason

Although reason is essential to any inquiry into the nature of knowledge, what is meant by reason has, again, confronted the minds of philosophers for centuries. However, the question, what is reason? can be approached by stating that thoughts are ideas, and ideas are engendered by our faculties of perception and conception. Whereas perception can be regarded as our awareness of the sensations derived from our receptor faculties, conception can be regarded as consisting of the recall of impressions which are regarded as consisting of the recall of impressions which are registered in memory, as well as the rearranging of such impressions into a new order and mental image; e.g., the faculty of imagination, is to conceptualise. Thus, reason can be referred to as the most precise and intentional integration and association of our ideas. During this process, the mind seeks a definite relationship between particular ideas, so as to attain a satisfactory conclusion. This conclusion depends wholly upon the arrangement of the ideas of which it consists.

The two general methods of reasoning are deductive and inductive. In applying deductive reasoning, one works from the general idea or principles to particulars. Thus, the deductive process begins with a general idea which is not self-explanatory to the mind: which is not conclusive in itself. This reason seeks, via the use of progressive analysis, to see how this inconclusive idea can be realised as a comprehensive whole, instead of an undefined thought. For example, is intelligent life a universal cosmic phenomenon, or is it limited to earth only? The answer could begin by a procedure of deductive reasoning: i.e., seeking those elements which have a relationship and which prove or disprove the concept.

In the inductive process of reasoning, one takes an idea which is perceived to be complete in itself, and then determines by observation and analysis how it may be combined with other particulars to form a general idea. Thus, one works from particular (idea) to the general (idea).

Reasoning becomes accepted as true knowledge only if its conclusions are eventually universally presented objectively. Otherwise, these conclusions are only beliefs, a substitute for knowledge.

From the above, it does not seem that to gain knowledge, we place our greatest dependence upon our receptor faculties. Because these faculties have been known to be sometimes deceptive. On the other hand, it cannot be said that when a majority of persons perceptually experience an object in the same way, such is reality. Because the noumenal quality of the object, i.e., the thing in itself, may be quite different from what humans perceive. According to Aristotle, noumenal phenomena are opposed to the phenomena of the senses. Such phenomena are reality and therefore true knowledge.

4.5.2 TECHNOLOGY KNOWLEDGE

4.5.2(a) Personal/Impersonal Knowledge

By now, it is apparent how difficult it can be to define knowledge, and technological knowledge is not an exception. Perhaps categorising knowledge into "impersonal" and "personal", may prove helpful.

The brief comments about faith, belief and reason, suggest that knowledge can be "impersonal", no matter what value we may place upon it. Knowledge is something that is external to us, until it is experienced through problem-solving. What this means, in a sense, is that knowledge stands passively by and must be understood and made into experience by some process (problem-solving). This view is associated with the traditional conception of knowledge:- knowledge as abstract and impersonal. But knowledge associated with technology appears to be personal and practical, and therefore not external to man. [Heidegger, Polanyi (1958), Schon (1967), Wesson (1980)]. Polanyi's "tacit" knowledge (much of which is inaccessible to formal academic study, but transmittable by personal contact) know-how, (Laudan, 1984) and the aim and/or goal of technology (practical/problem-solving) are clearly underlined here.

As will be implied later, when knowledge is personal and practical, rather than abstract and impersonal, our ideas become "tools" into which, as it were, we "pour" ourselves to use Bolton's phraseology (1985), in order to discover or know things.

From the epistemological standpoint, the "knowledge" involved in technology makes itself clearer, only when technology (as a form of human knowledge) is related to other forms or human knowledge, particularly science. From this perspective, technology is perceived as "practical activity", or a way of acting or action, which (as distinct from mere behaviour) involves some beliefs. This practical activity or knowledge, ranges from skills derived from concrete experience (Feibleman, 1961), to a more general knowledge of how to cope with our environment. (Jarvie, 1967).

Skolimowski (1966), in sympathy with Kotarbinski's praxiology, reveals the distinctive structure of technology, using the distinction between science and technology.

In other words, put in a wider context, the practical knowledge or technique, involves "know-how" as well as "know-that". A way of acting or technique implies detailed procedure and skills, and their application. This complex procedure comes into being through knowledge. Skill is the ability to use one's knowledge effectively. The common synonym of technology, "know-how", presupposes "know-that". For there cannot be "know-how" without "know-that" (knowledge).

4.5.2(b) "Knowing That" and "Knowing How"

This distinction of knowledge between "knowing that" and "knowing how", was the focus of Ryle's book entitled, **Concept of Mind**. Although "knowledge that" is regarded as theoretical, and "knowledge how", as practical, Ryle has forcibly argued that not all "knowledge how" presupposes "knowledge that". To argue otherwise will result in an infinite regression, because every item of theoretical knowledge requires formulation and application; this even applies to "knowledge how". Consequently, in some sense, "know how" is prior to "knowing that". In any case, such distinction need not be so sharp, because there can be forms of knowledge that are both theoretical and practical at the same time.

In this respect, the distinction can be made between knowing how to do something and merely being able to do it. Due to the possibility that some animals are able to do things instinctively without really knowing how to do those things, "knowledge-how" normally implies some understanding and knowledge of principles involved in the activity in question. Moreover, it might be wrong to speak of "know-how" where there is no such understanding. If one can do something, it is because one has learnt the procedure. Whether or not a person can say how he does such things, if he has learnt to do them, he in some respects knows the principle involved. Thus, "knowing-how" is knowledge of a technique, the principles of which can be formulated in theory, whether or not they can be put in practice. Tech niques are acquired through learning, and reveal themselves, in a certain flexibility in the circumstances in which they are manifested. It appears true to say, that a person does not know how to do something unless he can do it. The exception is where he knows in theory how to do it, although he cannot do it in practice. In other words, he knows the principles, but cannot apply them. Since we cannot speak of "knowing how" unless there is a good reason for the ability, "knowing how" and "knowing that", become parallel. And the locution, "knowing how", is intelligible to use.

4.5.2(c) Science and Technology Distinction

The character of technological knowledge can also be elicited and thus, the relationship between "knowing how" and "knowing that", made clearer, by examining the distinction between science and technology.

Clearly, the aims pursued by technology must be different from those pursued by science. While technology aims at effectiveness, science aims at truth. (Skolimowski, 1966). Sharp differences are created by making the aim of an activity effectiveness rather than truth. For what is effective, may be true or it may be false. To illustrate this point, technology, as knowledge of sorts (know-how), tells us something about what works in this world. However, what is regarded as effective in one part of the world, may be a purely contingent matter in another and will depend also on the degree of effectiveness demanded in technology. For instance, it may be found, that a particular measure '(X)', deals with a problem '(Y)' 95% of the time; we may feel that '(X)' deals effectively with '(Y)' 95% of the time, but may not be too sure. We may also know, that 5% of '(Y)' cannot be dealt with by

'(X)'; the cause of '(X)', and the reason '(Y)' deals effectively with it may be unknown to us. What we can safely say, is that '(X)' sometimes deals with '(Y)' completely. Thus, in technology, truth is also valued, because attempts are made to find out why '(X)' works as it does, but meanwhile, it is seen as a good technology, with effective percentage of 95.

It is obvious that truth is not the same thing as effectiveness. But when knowledge is mentioned, knowledge of truth springs to mind. What is being suggested here is that on a different logical level, knowledge of effectiveness is also knowledge of truth. In other words, knowledge of effectiveness is true knowledge of what is effective, rather than why it is effective, and thus, an aspect of the whole truth. (Jarvie, 1967).

The idea of knowledge as proven truths was left behind for us by the ancients. Contemporary philosophers discarded this idea, and came out with one which decreed, that only tautologies of logic and mathematics can be proved. Nevertheless, the new view of the concept of knowledge also discards proved truths, and, in their places puts scientific reservations like this one: " This is only a hypothesis, the best that can be suggested at the moment. It will be revised, as soon as there is reason to doubt it." So that in recent times, knowledge, is generally regarded as putatively true statement: i.e. statements which are tentatively advanced in the belief that they might be true and should be tested. For instance, scientific knowledge is generally regarded as putatively true statements about the structure of the world. To say that water boils at the temperature of 100 degrees C, is not a truth about the structure of the world, but a contingent fact about our environment. And technology seems to be closer to knowing a lot of things whose logical status is the same as the boiling temperature of water, instead of things like Newton's laws or Einstein's mass-energy equation. In other words, science aims at true laws which are universal, and explains the facts of the case about them. Technology (know-how), is knowing what works, how to do things (design), with a precision as high as is demanded.

Let it be taken for granted, that technology is an all-embracing word, encapsulating within itself in,

> applied science, invention, implementation of applied science and invention, maintenance of the existing apparatus,

and that these last two concern planning and engineering (purely practical matters). Beyond these practical matters, invention takes over. As it is important to science and other fields, it consists in discovering a way of doing something which has already been known to be possible. For example, persistence of vision makes the motion picture possible; but a great deal of inventiveness was required, in order to make this possibility and actuality. Although the character of the inventor's (technologist's) knowledge, is not on a fundamental level in the sense that pure science is, nevertheless, it is a sort of

> ingenuity in bringing together separate pieces of mechanical and other information and applying them to a particular problem.

The information sometimes concerns quite commonplace facts about our world. The inventor (technologist) therefore demonstrates how, when these are put together in a certain combination, they do a certain job. It is clear from what has been said so far that a special kind of ingenuity and mechanical intuition, constitute the character of the inventor's knowledge; a character which seems to be quite different from that of science. The implementation of what has been invented is purely a practical matter, which is also technology. A typical example, is the builder who carries out the architect's blueprint. The applied science component, is considered to be the application of abstract theories to the world. 'Applying', is regarded here as deducing from scientific theories with the help of some statements of fact, consequences that can be tested and applied. Scientific theories are abstract and fundamental; with the help of concepts, like space, mass, force, etc., the explanation of what the basic structure of the world is composed of, is made possible. Applied science attempts to show how this can be done, by actually deducing those descriptions of the phenomena they do explain.

In some ways, technology can be seen as a tool invented by the inventor (because he shows us how, when he puts mechanical and other information etc., together in a certain combination, they do a certain job), which is shown to be possible by pure scientists and actually explained by deductions and calculations by the applied scientists. Well, technology as "know-how", as a tool, cannot be knowledge. A tool is not knowledge. A screwdriver, or a hammer, or a chisel, or for that matter a lathe machine is not knowledge. They are things. However, knowing that a real screwdriver, or a hammer exist, knowing how they can be used and constructed, may be regarded as knowledge. If technology is regarded as a tool, or what the inventor invents, or what the applied scientists do to show a theory explains, then it has no place in the structure of knowledge.

Yet according to the pragmatic philosophy,

> the only way which you can know that you know-that something, is by trying it out, by making it work.

But is it really true that the argument that a screw driver or a lathe machine etc., cannot be knowledge? Are we being misled or misguided by a word. Granted that a tool like a hammer, is not, and in addition to being a thing, a piece of knowledge: what about a piece of knowledge? Is it not a thing and can it also not be a tool? $E=mc^2$, is a piece of knowledge, a theory or an equation. Is it not also a tool? Has this piece of knowledge not been used to plan, build and calculate the effect of the atom bomb? Is a tool not simply something which a man uses to increase his power over (or control) the environment? Is it not in this sense that the whole scientific and even intellectual endeavour is considered an outgrowth of our attempts to cope with our environment by learning about it?

4.6 TECHNOLOGICAL KNOWLEDGE

4.6.1 AS KNOWLEDGE OF PRACTICE

To distinguish knowledge as distinctly technological, it has to meet certain criteria. The criterion of utility alone is insufficient, because technological activity does not necessarily require technological knowledge; e.g. by using the knowledge of thermodynamics to improve the full efficiency of an internal combustion engine does not make that knowledge inherently 'technological'. Thermodynamics is scientific knowledge. Thus, technological knowledge cannot be so called on the basis of a criterion of technological activity, processes or goals, otherwise the argument would be logically circular. Just as it would be incorrect to say that knowledge is technological simply because it is used for a technological end, it would also be incorrect to assert that technological activity only involves technological knowledge.

According to Frey (1991), what makes technological knowledge distinct from other forms of knowledge, seems to be its dimension/range from tacit to analytical/symbolic knowledge. Tacit knowledge operates at both intuitive and subjective levels. This knowledge cannot be verbalised, and is exemplified in the hands of highly skilled craftspersons. At the tacit level, knowledge requires little or no conscious effort or reflection. It is highly practical and efficient. Analytical/symbolic technological knowledge (which is at the opposite extreme), is frequently expressed in mathematical formulations which, in turn, look very much like scientific laws, e.g. in many engineering models. It appears that there is a continuum of knowledge that draws from practical experience of designing, developing, trouble-shooting, and repairing technological artefacts. Whereas one end of the continuum has the highly systematised and formalised knowledge of the engineering profession, the other end has the tacit knowledge of the skilled tradespeople and artisans. Between these two extremes, there is a huge range and degree of experiences, which are directly related to technological activity. This cumulative experience after a period, achieves some degree of formality. The result of the convergence of this range of activity, experience and practice, is technological knowledge. Thus, making technological knowledge, 'knowledge of accumulated practice', which is directed toward the activity surrounding the development, maintenance of technological artefacts. The 'artefactual thrust' of the activity distinguishes technological knowledge from the other forms of praxeological knowledge (knowledge of practice), such as those used by dentists, medical doctors, educators, journalists, etc. According to Frey (1991), maintaining the sense of 'range' is vital if an understanding of technological knowledge is not to slip out of our minds. This is probably because this accumulated knowledge of practice covers a broad spectrum of technological experiences. Otherwise, incorrect and inappropriate restrictions in what constitutes the knowledge base could occur. For instance, it is inappropriate to identify engineering knowledge as 'the' source of technological knowledge. Because a large segment of the 'accumulated knowledge of practice' spectrum would be eliminated, and thus be incorrect. Rather, technological knowledge should be seen as a function of a range of activities that can be classified as technological.

By establishing that certain activities are inherently technological (generally focused around the trouble-shooting, design, development etc. of technological artefacts), and that technological knowledge as an accumulation of practice exists, the way becomes clear to assert that technological activity requires at least minimal levels of technological knowledge (that is uniquely, technological in nature). This usefulness or applicability of un-technological knowledge for engaging in technological activity is being played down. Neither is it suggested that technological knowledge is the only applicable knowledge, or that that knowledge becomes technological when driven by technological purposes. The argument, simply and pragmatically, is that technological knowledge is a necessary, but not a sufficient condition for technological activity. What Frey (1991) is implying is that some element of a formalise or a systematic knowledge is required. The idea of 'artifactual' thrust emphasised by Frey (1991) has guided and informed this investigation by stipulating the criteria necessary for a task to be technological.

4.6.2 TECHNOLOGY AS PROCESS

To establish the vital link between technology and design, technology as process must be closely examined. The term "technological problem-solving" provides a useful mechanism for discussing technology as process. This is so, not only because technological problem-solving is distinct from other forms of problem-solving, but also sufficiently robust and inclusive of the full range of technological process.

It is important to clarify what technological problem-solving is and how it can be distinguished from other forms of problem-solving. A conceptual criterion would be required to clarify and structure technological problem-solving. Problem-solving is a critical process skill that involves virtually all aspects of existence. Clearly, all problems are not technological. Problem-solving is a process which has been identified and promoted by diverse academic disciplines such as mathematics, psychology, the physical sciences, the arts. In different contexts and in unique ways, problem-solving processes have been used by all. It is hard to imagine any field of endeavour or type of activity that does not engage the problem-solving faculties of people; e.g. an engineer calculates the material and dimensional requirements for a load-bearing structural member. Since it is difficult to imagine an aspect of life that does not require problem-solving, the term problem-solving itself has evolved into a generic construction which covers a wide range of different types of activity. The 'problems' of an alcoholic, besieged with numerous financial, marital and personal difficulties, appear to have little in common with the 'problems' that a design engineer faces in attempting to develop ways to dispose of hazardous waste safely. Given this and numerous other examples, how can technological problems be distinguished from other types of problems? A conceptual framework for problem-solving that was inclusive of all form of problems and able to distinguish technological problems as unique from other forms, was needed. A classification structure based on Newell & Simons' notion (1972) of 'problem space' was developed. According to this notion, problems exist within a context that is defined by the resources, solutions, and processes used to address them. This notion was used as a launching pad for the more detailed analysis of technological problem-solving. Problem-solving space includes three primary dimensions, namely resources, primary process and goal 'thrust'.

Resources: concerns all that is brought to bear on the solution of a particular problem, be they physical, material, psychological and knowledge. There are no restrictions on the amount or type of resources that could be used to address a given problem.

Primary Process: included in this area is a vast range of terms such as designing, repairing, negotiating, counselling, testing, investigating, hypothesis, etc. These processes include a range of activities or techniques that are employed by problem-solvers, using available resources to solve problems.

Goal Thrust: concerned with the motivation or directionality of the problem-solving activity. Problem-solving activity is intrinsically purposeful and directional. For problem-solving to exist, a problem must first be identified that is capable of eliciting action. This sense of action, motivation and directionality constitutes goal thrust.

These three primary dimensions interact, and their relative values help in distinguishing between the various types of problem-solving space. Individually, each, except goal thrust, cannot be used for classification of problem space. However, whilst resources brought to bear on a particular problem are valuable in almost any type of problem situation/problem space, they cannot serve as a basis for classification of problems. Primary processes include tasks such as designing, developing, making, repairing, planning, etc. It can be argued, that primary processes are basically linguistic constructions that have emerged out of the cultures of various fields of endeavour. For instance, engineers would use terms such as design and development, while counsellors refer to active literacy, planning and directing. A closer look, however, would indicate that these various terms actually share much in common in terms of cognitive and practical processes. Their distinctiveness has evolved as various communities of practice come to attach common sets of terminology and language to their practices and procedures. As with resources, primary processes are insufficient for use as a basis for classification. The goal thrust component was the primary distinguishing characteristic that was sufficient for developing inclusive classification for problem-solving. Custer (1994) identified three types of goal thrust namely:

(a) those concerned with the creation of primary physical artefacts;

(b) those concerned with the development and maintenance of healthy, efficient and meaningful relationships; and

(c) those concerned with the need to understand the workings of the natural world.

It was these three primary types of goal thrust (motivational) which provided a useful mechanism for structuring three primary problem spaces: technological, social and natural/ecological. Here then was the model that provided a useful conceptual framework for distinguishing among the various forms of problems and for conceptualising technological problem-solving as distinct from other forms. To say that technological problem-solving process occurs within a unique domain (e.g. technological problem space), raises the question; 'Are there processes that can be said to be uniquely technological?' Conceptualising technological processes in terms of (a) problem-solving; and (b) technological problems as occupying a distinct problem space, seemed to point to the answer.

Having established the uniqueness of technological problem-solving (based on a problem space that is uniquely technological), Custer (1994) developed a two- dimensional technological process matrix, which he used to distinguish various forms of technological problem-solving one from another. These two dimensions are defined in terms of (a) goal clarity and (b) problem complexity. (see appendix -12) The goal clarity continuum ranges from problems that are posed in terms of a single, clearly delineated goals at one extreme to those that are multiple, ill-defined, complex and perhaps even obscure at the other.

The second dimension focuses on problem complexity. It covers a broad knowledge requirement (both in terms of type, level and knowledge transfer demands), linearity and degree to which solution paths can be formalised into structured rule systems. Thus, by so doing, Custer (1994) analysed technology as process and revealed the conceptually distinct nature of terms traditionally used, such as inventing, development, repairing, design/innovation, trouble-shooting. The matrix also provided a conceptual framework within which technological problem-solving processes could be structured. Each quadrant in the matrix included three dimensions (procedures, personality characteristics and knowledge) that are unique to that type of technological process.

Procedures: referred to the various approaches used to progress through a technological problem-solving activity. They included a set of procedures that generally represented a range of systematisation. The possibilities extended from haphazard to the rigorous application of routine and algorithmic procedures. Referring to the technological process matrix, experimental procedures could be most closely associated with the highly complex, multiple solution problems that were more typical of problems associated with the Invention Quadrant (e.g. designing a computer software routine capable of processing fuzzy logic). The Design/Innovation and Development Quadrants were typified by processes that were more heuristic in nature. A coalescing of techniques based on experience, informal trial and error, and feedback were presented in processes of this type.. Algorithmic procedures were most typical of processes associated with singular goals and relatively low problem complexity (e.g. trouble-shooting faults in electronic circuits, or following an established plan of procedure to assemble a product). Processes of this type were located in the trouble-shooting Quadrant. It was important to note that a range of expertise might be represented within each of the quadrants, and that this expertise, was not necessarily transferable across quadrants. Neither did the expertise required to solve a specific type of problem within one quadrant transfer to a problem within that same quadrant (within quadrant transfer). For instance, expertise in trouble-shooting a faulty electronic circuit in a logic board does not transfer directly to expertise in trouble-shooting a hydraulic or pneumatic circuit, because a different knowledge base for each problem is required to use the procedure. This is explained later.

Personality Characteristics: Since technological problems and activity were meaningless in the abstract, technological activity would, by definition, be human activity. Given this and the diversity of human abilities and styles, it was important that the dimension of human cognitive style characteristics be incorporated into the problem-solving structure. For instance, the inventive process could be described, partly, as a function of divergent thinking and creativity. Whereas, the trouble-shooting process generally required convergent thinking and an application of established procedures. However, it was important that personality and cognitive style dimensions be integrated into the technological problem-solving framework, for both conceptual and practical reasons. Conceptually, problem-solving could not be abstracted from the realm of human of activity and ability. Any attempt to do this, would typically foster reductionistic conceptions of the problem-solving where all people, irrespective of their individual characteristics and abilities, theoretically approach all problems armed with a generic set of steps or procedures. In practical terms, certain personality characteristics corresponded with the degree to which individuals were successful in thinking out solutions to specific types of problems. For instance the tenacity, systematic thinking and strict attention to detail which would be necessary to debug a complex computer program, could well prove to be restrictive in a creative and open-ended problem situation. Clearly, from the above, the human dimension (cognitive style, personality characteristics, type of knowledge, etc.) would be an important and necessary variable that must be incorporated into a conceptual framework for technological problem-solving. In other words, individuals do not simply bring themselves to problems that have been conceived in the abstract, rather, problems must be conceptualised, at least to some degree, as a function of the people (their expertise, personality, cognitive style, etc.) who attempt to solve them.

Knowledge Requirements: In examining the nature of technological knowledge, the conclusion was that it was a distinctive form of 'knowledge of accumulated practice'. It was clear that while the idea of the 'knowledge practice' was useful in the abstract, it became quite specific when transformed into process. For example, for a technician to be able to trouble-shoot a faulty electronic circuit, it would be useful, if not essential, for the individual to possess specific 'knowledge of practice' in electronics. That same type of knowledge, even though at a high levels of expertise, would be of little value to the same individual when faced with the challenge of specifying the structural requirements of a load-bearing beam for a large building. It therefore seemed logical and appropriate to define, partly, specific types of technological processes (development, design, invention, etc.) in terms of the kinds of knowledge required to address them.

In sum, it was possible to define technology as process. These processes represented arenas of activity generally focused around the performance of technological activities. Technology as process was defined generally as problem-solving, and this was a function of goal clarity and problem complexity. This established the link between technology and design. Furthermore, certain personality types, cognitive styles, learning styles, psychological variables, etc., would have effect on how well different individuals were likely to be able to solve types and configurations of problems.

As maintained earlier, the process in Technology with Design provides the vital link. Process, according to Johnsey (1995, p.195) is the way we go about achieving an end. The separate part of the process can be referred to as process skills. When the end sought is the solution to a practical open-ended problem then, in a very broad sense, it can be referred to as <u>problem-solving</u>. Moreover, where the end is the fulfilment of a need, or a designed product then, design process has been used.

Design and problem-solving are the same thing. Implied in the above definition is a methodological characteristic. Technology process linked to design can take different forms, such as algorithmic, heuristic and experimental. Design is about preparing to make a product and this is often followed by making and testing. By design only, production of such things as drawing in preparation for making, is implied.

Various modes of design have been put forward (see appendix 12). However, Eggleston (1996, p.30-31), has illustrated the similarity in the analytical process of enquiry between the two processes (technological and design). Without being critical of each model, they have been presented in appendix-12 for the purposes of showing how technology through design has manifested itself in schools over the past years. Some of these models are linear and others are cyclical. They have all been presented linearly for the sake of clarity.

Most of the models have the essence of the outline put forward by Assessment Performance Unit (APU), namely, Investigation, Invention, Implementation and Evaluation. In the mid-eighties, linear or cyclic process describing

> .... a procedural path which can be broken down into a developmental sequence consisting of a number of related areas of activity (Johnsey 1995, p.201),

was a typical approach to design and technology in Britain. To a large extent, it has influenced the developments in this area at both primary and secondary school levels.

4.7 MODERN DAY CONCEPTION

From what has gone so far, two complementary frameworks of clear, conceptual definitions of technology have emerged. Whereas some authors see the essence of technology in the fact of human activity (action processes involved), others see it in the methodological character of the procedures employed (purposeful activity leading to object making - material substratum).

It is appropriate at this point to say that these two frameworks are not fundamentally different, but complementary. Both of them are looking at the same thing from different points of view which are not necessarily incompatible. After all, the systematic procedure of the methodology employed in technology, which one of the frameworks emphasises, is more or less a natural systematisation of human activity, which the other framework stresses. In other words, to say, on the one hand, that technology is a means to an end, and on the other hand, that it is human activity, is to imply that the two definitions belong together. For to posit ends and procure and utilise the means to them is a human activity. The manufacture and utilisation of equipment, tools and machines, the manufactured and used things themselves and the needs and ends they serve, all belong to what technology is.

This definition of technology, according to which it is means and a human activity corresponds to the current conception of technology.

This "broad" conception of technology considered thus far, has largely influenced schools' definition of technology. This is taken up later, but for now, attention will be directed to the philosophical foundation of the two principal views of technology presented above.

CHAPTER - 5

THE PHILOSOPHICAL FOUNDATION OF THE TWO PRINCIPAL VIEWS ON TECHNOLOGY

5.1 INTRODUCTION

Each of the two principal views about technology identified, has a philosophical foundation which will be examined. The "narrow" view, in which technology is not regarded as "knowledge" but associated with skills, is rooted in Plato-Aristotelian philosophy. Therein, technology is not part of Plato's "mind" but "body". However, the "broader" view, in which technology is regarded as knowledge, purposeful activity, and process, is associated with the Pre-Socratic philosophy, as well as, or more recently, Heideggerian philosophy. Within this philosophy, the superiority of the "mind" over "body" suggested by Plato above is dismissed, in favour of the unity of both. Technology is regarded as the very foundation of all forms of knowledge.

5.2 NARROW VIEW: PHILOSOPHICAL FOUNDATION

5.2.1 THE CONCEPTION OF TECHNOLOGY WITHIN PLATO-ARISTOTELIAN TRADITION

Labelled as the traditional conception of technology, the Plato-Aristotelian conception of technology has dominated the scene for many centuries, and is still maintained by many philosophers today. Essentially, within this tradition, the description of the concept of technology as a form of human knowledge, is bitterly disputed (or rejected). Two 'powerful' arguments have been used, one by Plato and the other by Aristotle, to reject the idea of technology as a form of human knowledge. Whereas Plato used ontological judgement incorporating the distinction between mind and body to argue that technology cannot be knowledge, Aristotle deploys forcefully the notion of the 'neutrality' of technology to make the same point. This will be apparent as progress into the tradition is made. Plato's 'mind-body' distinction will be presented first, followed by the Aristotelian 'neutrality' of technology.

5.2.2 PLATO'S 'MIND-BODY' DISTINCTION

As Ihde (1979), and Russel (1946, p.861) remind us, the bitter dispute about technology as a form of human knowledge, is probably linked to the association of technology with practical skills, or machine technology. This dispute and the subsequent downgrading of technology, is indeed religious in origin, but orchestrated and subsequently extended to cover other areas of knowledge by philosophy, particularly Platonistic philosophy. The early philosophic concern excluded technology as an unimportant theme and concentrated on issues related to ontology and epistemology, because it is not immediately clear whether technology has any philosophical parentage compared to other forms of knowledge e.g., science. And to regard technology as applied science will mean that it is a forebear of philosophy, which obviously seems unlikely. What is then likely is that technology is dumb and merely an instrument, tool or slave of science. Furthermore, legends such as that of Frankenstein, have strengthened this thinking by pointing out that technology is created from "matter which is both dead and dumb" and later brought to life through the application of theory. Hidden in this argument is the ontological judgement, reminiscent of Plato. Chronologically speaking, technology is older than science. The knowledge involved in techne was praised but downgraded by the Greeks, but later recognised at least, as extant and powerful for human beings. Some historians like Lynn White, have suggested, that

> if the root of modern science took life in the Renaissance, that of modern technology, goes back to the Medieval time. (Ihde, 1979, p. xviii).

Yet still the philosophical roots of technology remain unclear, relative to science. Thus, the partial setback, or downgrading of technology, has been the responsibility of philosophy, which thinks of or considers itself more as conceptual engineering than material engineering. This thinking regarding technology, has dominated the scene for a long time. It turns out to be idealistic, and it is not unrelated to the long-standing distinction between theory and practice. To take for granted the primacy of theory over practice (or mind over matter), is to suggest, or imply, that technology is dependent upon science or that technology is made possible by science. A deeper phase of this distinction may be associated with the mind-body distinction. Accordingly, theory, as a set of concepts in some system of relations, is usually thought of as the product of the mind, while practice is often associated with the product of the body.

Thus, where there is a paradigm within the dominant tradition about the relationship between science and technology it is definitely one which assumes the primacy of science. The consequence is that technology is given less attention relative to science, and confirms the realistic interpretation which sees technology as applied or as an instrument of science. Within the Platonistic tradition, mind takes precedence over the body. In this respect, the phenomena of perception and embodiment in the 'body', are negatively evaluated, as lower on the scale of human activity than what is presumed to be a pure conceptuality. However, it will be remembered that in Plato's Republic there is a clear evaluation of the types or stages of knowledge. Therein, and as the allegory (or myth) of the cave will indicate, certain human capacities are valued more than others. For example, the lowest form of knowledge, imaging or seeing reflected shadows in the cave, results in a kind of perceptual type of knowledge: then on to mathematics knowledge (although still perceptual in the Greek sense), gradually rising upward to pure intuitions of forms; i.e. true knowledge - knowledge of forms. Accordingly, this sketch downgrades both perception and embodiment.

5.2.3 THE CONTRIBUTIONS OF THE GREEK RELIGIOUS IDEAS

Cultural reasons such as the ancient Greek religious ideas about the dualism of the body and soul, in which the former (body) is regarded as **"container"** of the soul (inferior), and the latter (soul) superior, ethereal, have also contributed to the downgrading of technology. In Greek religion the soul is regarded as ethereal and the inner direction of humanity toward the Good, a direction which is actualised by transcending beyond the body. This 'transcendence beyond the body' underpins, within the Platonistic tradition or theory, the negative value which has been given to both perception and embodiment. (Ihde, 1979, p.xx)

5.2.4 ARISTOTELIAN NEUTRALITY OF TECHNOLOGY

Aristotle, like Plato, regards technology in a narrow sense as

> a human arrangements of technics - (tools, machines, instruments, sciences and personnel) - to make possible, and serve the attainment of human needs or goals. (Hood, 1968, p.347).

According to this conception, technology is not an activity which in itself satisfies man's nature, rather it is something he does only in order to get through with it so that he can go on to something else. In other words, technology is not an end in itself but simply a means to some further end. It is something external to man's nature. Furthermore, the value or meaning of technology is determined by this 'ordering' towards something else; it is not thought to have any meaning in itself: it is NEUTRAL.

The neutrality in question is based, first of all, on the Aristotelian distinction between NATURAL and ARTIFICIAL objects, and secondly, on what he thinks <u>techne</u> or productive cognition is.

<u>Techne</u> within this tradition, is concerned with objects which are

> neither necessary nor according to nature. That is, with things which are not what they are necessarily, nor have any innate tendency to become what they might be, but with things which can be made into other things given the action of some human agent. (Hood, 1968, p.348).

5.2.4(a) Distinction between Natural and Artificial Objects

Aristotle starts his distinction between "natural" and "artificial" objects by contrasting forms given to matter by artisans with those given by Nature. Accordingly, artisans do not give form to matter in the same manner as Nature does. For the natural form of some thing, is intrinsic to that thing. For instance, an oak tree is an oak tree, because of some intrinsic principle which determines its growth and operations. The natural form has some power to define and effect operation: it is not neutral.

Thus, the form brought forth by technology in matter, such as technics and products, given extrinsically by the artisan, are artificial. Accordingly, when a new form is given to matter by the artisan, for example, the forming of a bed on some oak wood, the change which has been brought about is not a change in its natural form, but a change solely with respect to some externally imparted form. In other words, if one plants a bed and the rotting wood acquires the power of sending up a shoot, it will not be a bed that will come up, but wood. In this respect, because technical production has no intrinsic principles of definition or operation, they may be said to be neutral, and therefore, require humans for their operations.

5.2.4(b) Non-Utilitarian (Use) Vs Utilitarian (Instrumental/ Production)

The neutrality of technology, given the Aristotelian analysis, is even stronger, in that therein technological forms are presumed to derive not only their actual operation, but their value and meaning from the use to which they are put. For example, according to Aristotle, many of the actions, arts and sciences that exist now, have many ends. For medical arts, the end is health, for shipbuilding, it is a vessel, for strategy, it is victory, for economics, it is wealth, etc., etc. Each of these techniques and the artificial forms which they engender and utilise, has its meaning in the human purposes which they serve.

However, the unity which pervades this multiplicity of techniques and meanings, is rooted in the fact that technology is necessary to human life. Aristotle, was conscious of the importance and meaning of necessity, particularly as the basic necessity of living, e.g. the provision of food, shelter and clothing etc., call for the making and using of tools.

In what appears to be an endorsement of the superiority of non-utilitarian production over the utilitarian ones, Aristotle asserts, that the

> ability to make or produce something stands beyond the mere satisfaction of needs, because productive knowledge, like any other form of knowledge, is knowledge of universals. And for this reason, it is admired by others. (Hood, 1968, p.348).

Aristotle, however, insists that admiration is engendered not only because the product e.g. the chair, bed, etc., is useful, but also because its maker is believed to be wiser and superior to men of experience, who have knowledge only of individuals. Here the concept of human necessity seems to include more than the satisfaction of man's immediate biological needs: i.e., the end of technology is dimly perceived to be more than the fulfilment of the requirements of organic needs.

He cites instances, where primitive techne devoted a considerable portion of its attention to non-utilitarian productions from music instruments to ornamentation.

Technology

> include not only technics as means, but also the products it makes. Some of these products being directly used in the service of specific ends, such as items for consumption, eg., food to sustain life. (op.cit. p.348).

But many of these products are means to other products. For instance, machine tools which are used to devise tools, which in turn are used to make products, and so on, until the ultimate end is achieved. Hence, the distinction between instruments of production and instruments of action, is made quite clear by Aristotle in these words

> as production and action are quite different in kind, both require instruments: But the instruments which they employ must likewise differ in kind. (op.cit. p348)

It is therefore not too difficult to see why Aristotle regards the instruments of action as more important than instruments of production. To him, the end of technology is something which we can use (things which we call consumer goods) and not something that creates items of use (which we now call technics). Clearly, within this tradition, technic is an instrument (for instance, a hammer, or lathe machine), which belongs to production, and the instrument of action or practice, is an item of immediate use, (for example, chair, clothing). So that, a technic produces some results, but a consumer item produces no result, apart from its use.

Aristotle regards technology as the actualisation of certain entities (or conditions, if the effects that humans produce on animals, plants and the surface of the earth are included), and practice, as the manifestation of their function in living. Human life, according to Aristotle, is not production, but action. Instruments of action are for human existence, and they make its perfection possible by allowing men to go beyond production. In other words, it is not production, but certain activities, such as politics, philosophy, which in themselves perfect human nature and are pursued for their own sake. Aristotle asserts that it is such trans-technological activities and ends which determine the limits of the technical activity. Thus, to pursue techne, represents a finite task. It is after all the forms of technic have been established and some freedom from necessity has been secured that sciences (theory), become possible. Sciences are not for other purposes, but are ends in themselves. It is in the sciences (political theory) that the limit of technics becomes conceptualised.

Nevertheless, given that man, according to Cosmic Law and Order, has a nature or essence which is his proper function to realise, let us say that this nature or essence can be known, (if it is not ultimately knowing itself) by contemplating in the unchanging reality which encloses Cosmic change. The attempts by humans to deal with changing things are radically subordinate to theoretical or non-utilitarian concerns.

> For contemplation according to Aristotle, is at once the highest form of actuality since the intellect is the highest thing in us, and the objects with which the intellect deals are the highest things that can be known. (op. cit. p.348)

Clearly, Aristotelian is alluding to a hierarchy of activities in which technology represents the lowest kinds, and this is understood or implied. Accordingly, technology is regarded as

> a human arrangement of technics to serve the attainment of human ends; ends which are extrinsic to that arrangement and determined by the intelligible order of the Cosmos which in turn is reflected in the stable structure of the society. (op. cit. p.348)

The goal of <u>techne</u> (its product) e.g., the article of clothing, the house, etc., which the activity of making sees as its object, is strictly instrumental to something else from which it receives its complete justification. This 'something else' is the use to which it is put (i.e. wearing the article of clothing, living in the house) for the sake of activity that ultimately is its own end, viz. moral or intellectual activity. Technology is therefore subordinate to practical wisdom, to moral and intellectual activities which are their own justification (or can justify themselves.)

5.2.4(c) A Reaction to Aristotelian Understanding of Technology

As an immediate but quick reaction to the Aristotelian conception of technology, Hood (1968, p.349) thinks that such understanding of technology probably makes sense in pre-modern society. However, the difficulty with this understanding of technology is:-

(1) that the modern scientific view of nature does not lend support to its metaphysical base;

(2) that, practically speaking, the search for concrete limits to technology cannot be found in present-day culture.

This is particularly so because the development of technology since the 19th century has been so great that nothing in our culture remains outside of it. Thus, the problem of deciding what is the total arrangement, to which technology is referred, becomes apparent. What is a means in one context, becomes an end in another. For instance, a hammer is used in the workshop, but it is made in the factory; what has been a product or end, becomes a means. This analogy applies to even more complex technic than a hammer, e.g. the production of automobile.

The point being stressed here is that a hammer (or technic), cannot and should not be approached as if it is simply a neutral instrument which attains its value (or otherwise) from some use (or misuse) which is, a priori, clear and settled. Thus, it is more appropriate or sensible to approach this important technic as a

> dynamic member of a means-end continuum in which it functions as an indefinite number of means (for transportation, recreation, profit, etc.) as well as concurrently serving as an object of immediate possession and enjoyment. (op. cit. p. 350)

As a consequence, we do not seem to be able to distinguish arrangements of technics from things which are not technics in any final way, because it is not possible to distinguish means from ends in our modern technological complex. With such complexity, we are forced to acknowledge that

> means and ends are relative and interchangeable, and neither has a clear moral superiority over the other. (op. cit. p. 350)

Another analogy which seems to 'dismantle' the traditional means-end distinction, is that which has to do with occupation. It is often thought that occupation is a means for making a living. But it is not often realised that equally important is the fact that occupation provides an opportunity for realising some of our unique capacities as individuals.

It must be remembered that this means-end distinction, forms the basis upon which the neutrality of technology rests. The fact that the structure of technology appears to elude our grasp, disappearing in a confusion of interrelationships, and resulting in man himself being lost in technology, calls the Aristotelian assumption into question. In Theodore Roszak's words see (op. cit. p.350)

> Those of us who find ourselves distressed or even horrified at the shape that the technological society is forcing upon our lives find ourselves again and again brought up short by the familiar cliché that technology (in both its mechanical and its organisational aspects) is after all a neutral force that can be wielded for man's well being as well as for his harm.

However, although the modern situation appears to contradict the Aristotelian understanding, there continue to be protagonists for the traditional conception, with the tacit understanding along the way that the structures of technology can possibly be fixed by relating it to something external. It is unclear under the present circumstances, what this something may be.

5.3 DESCARTES: SPIRITUAL AND MATERIAL SUBSTANCES

It is perhaps relevant with respect to the notion of 'mind-body', to bring in Descartes, who, described as the "father of modern philosophy", has also endorsed Platonistic idea of mind-body distinction. His assertion that man has immediate knowledge of his mind by a kind of interior illumination, greatly superior to the kind of knowledge which he has of material things, is a testimony to his endorsement. According to his assertion, mind dwells in the bodies and share none of the characteristics of material things.

However, his idea about spiritual and material substances left no doubt in his mind about the existence of spiritual reality in general and in particular, man's spiritual mind. This idea has been an integral part of Descartes' system, and not merely the relic of an old tradition. This is an idea which is apparent in his book Discourse on Method, wherein he attempts to reconcile deductions from mathematics with concepts of universe created by God.

In one of Descartes' numerous assertions on mind-body, he describes the material world in terms of matter, identifiable with geometrical extension and motion. He seems to believe, that a fixed amount of matter and motion was put into the world when God created it. Having decided on the mechanical laws that will govern all nature, God did not want to interfere with the self-running machine which he had created. He ascribes to as machines, all bodies including living bodies, inorganic matter. They are ruled by the same inexorable laws and susceptible to analysis by quantitative methods of mathematics. According to Descartes,

> "man's body is nothing but a statue or machine made of earth".

But man he says,

> as a whole, cannot be reduced to a member of this mechanical system. Because he possesses a spiritual mind which transcends the material world and the determining laws of efficient causality which governs this world. (Copleston, 1963, p.24)

He then draws the distinction between those organised bodies which are and those which are not connected with self, so as to form a substantial unity. Whereas the latter bodies are explicable in behavioural concepts, in terms of mechanistic actions, stimulus-response model and conditioning processes, the former bodies, which exist in a real union with a relational, volitional self, require purposive models to explain their actions.

Despite the problem in Descartes' interpretation of man as consisting of two distinguishable substances (mind and body), he still maintained that the mind can and does act on the body. If we assume that man consists of two clearly distinguishable substances, then we will expect his nature to tend to fall apart and no longer to possess a unity. It then becomes difficult to account for the evident facts of psycho-physical interaction.

5.3.1 SPIRITUAL vs CORPOREAL

In another instance, Descartes talks about spiritual and corporeal substances, where Platonistic similarities are much in evidence. According to Descartes, thinking is the principal attribute of spiritual substance. He is more inclined to maintain that spiritual substance is in some respects always thinking. But he had no doubt that the mind begins to think at the same time that it is infused into the body of an infant, and that it is at the same time conscious of its thoughts, although it does not remember it afterwards. Why should the soul (mind) not always think when it is a thinking substance? And why is it strange that we do not remember the thoughts it has had when in the womb? If the essence of the soul (mind) is to think, then it must obviously either always think or cease to exist when not thinking.

With respect to the corporeal substance, Descartes asserts that it has as its principal attribute, extension. Figures and actions cannot be conceived without extension. So that extension in length, and depth, constitutes the nature of corporeal substance.

> These attributes are inseparable from the substances of which they are attributes. But they are also modifications which are separable, not in the sense that they can exist apart the substances of which they are modifications, but in the sense that the substances can exist without these particular modifications. (Copleston, 1963 p. 128)

For instance, though thinking is essential to the mind, the mind has different thoughts successively. Furthermore, though a thought cannot exist apart from the mind, the mind can exist without this or that particular thought. Similarly, though extension is essential to corporeal substance, a particular quantity or shape is not; because they (e.g. size and figure) can vary. Descartes uses the term 'modes' to describe these variable modifications of attributes of thought.

However, from the above, it is clear that human beings consists of two separate substances and the relation of mind to body is likened to that of a pilot in the ship.

For Descartes, there seems not to be any intrinsic relationship between the two factors. (i.e. mind and body). Because by his saying, that I am a substance, the whole of which is to think and therefore not included in my clear and distinct idea of myself as a thinking thing, it would then seem to follow, that the body does not belong to my essence or nature. Consequently, I am a soul lodged in a body.

Obviously, if I can move my body and direct some of its activities, then the relationship between the soul and the body at least is such that the soul stands to the body as mover to moved, and the body to the soul as instrument to agent. The mind-body relationship just described, is analogous to the pilot in the ship. Therefore, the theory of my clearly and distinctly perceiving myself to be merely a thinking being leads to the conclusion that nothing corporeal belongs to the essence to man, who is hence entirely spirit, while his body is merely the vehicle of the spirit.

5.4 SUMMARY OF THE NARROW CONCEPTION OF TECHNOLOGY

The conditions have been stated in which technology is not knowledge, because it is not part of Platonistic mind-body distinction. Aristotle equated the end of technology, exclusively with use. He says

"artefacts do not exist for their own sake."

So that, if the roof of a house collapses after a carpenter builds it, carpentry would not have realised its purpose, even when the carpenter was satisfied with the exercise of his craft. Because use is not an end in itself, its final purpose is the same as that of all human action - namely, the maintenance of human life and its perfection in which man attains "eudaemonia", and his supreme happiness, which, according to Aristotle, consist of either a life of political activity or contemplation. Technology gives man the possibility of attaining perfection; of entering into the full realisation of his nature but, does not formally constitute that possibility. To achieve human perfection man needs to cultivate not just technology, the habits and know-how, which constitute productive cognition, but a life that transcends mere making. Descartes reinforced this view, himself being a follower of Plato.

CHAPTER - 6

"BROAD" VIEW: PHILOSOPHICAL FOUNDATION

6.1 INTRODUCTION

Thus far, the philosophical conditions have been in which technology is somehow not knowledge, because it is not part of Platonistic idea of 'mind' but 'body'. The "broad" view, which is in direct contrast to the Platonistic one, does not make the distinction between "mind" and "body". Thus, it can be identified with pre-Socratic philosophy. In the pre-Socratic philosophical era, there is not the same distinction between mind and body, although Parmenides (fragments B5 and B6) indicate that the distinction in question has been built-in already, perhaps to serve a useful purpose of clarifying concepts. However, Plato is directly held responsible for starting it all.

Pirsig (1974), has tried to link pre-Socratic philosophy to today's thinking about technology. In effect, he argues for the unity of mind and body, the priority of action over mind. There is also a mystical overtone, and a pre-Socratic philosophy, where there is a mystical element (in which there is the unity of thinking and doing, which has been destroyed by Plato). Greek philosophy, after all, is not just Plato but includes what happened before Plato as well. And as will be implied, what happened before Plato is in tune with what is happening nowadays.

6.2 THE PRE-SOCRATIC PHILOSOPHY MIND-BODY UNITY

The contemporary argument for technology as a form of human knowledge, is not based on the idea of the separation of mind from the body. Instead, it is based on the unity of these seemingly separate entities. The origin of this philosophic idea is undoubtedly pre-Socratic philosophy. The various texts on the pre-Socratic Greek (e.g. Kitto, 1950, p.173), relate that, during this philosophic era, the sharp distinction which the Christian and the Western world drew between the body and the soul, the physical and the spiritual, is foreign to the Greek at least until the time of Socrates and Plato.

Greek philosophical thinking during this time, was expressed in terms of 'oneness', 'wholeness', unity of things. The poet Homer expresses this thinking, despite his love for particular detail and individual character. He fixes things firmly into a universal frame. Moreover, many Greeks such as Solon have aspired to and became several things: a political and economic reformer, man of business and a poet all at once. The "modern" man divides, specialises, thinks in categories. On the contrary, the pre-Socratic Greek mind takes the widest view and sees things in an organic whole as the speeches of Cleon and Diodotus indicate. (Kitto, 1951).

More illustrations of the 'oneness' or 'wholeness' in pre-Socratic Greek mind, can be found in the Greek language. Therein, there is an apparent refusal to specialise the meaning of words. According to Kitto(1951, p.170), the pre-Socratic Greek did not divide (1) concept into different, though parallel categories; (2) the moral; (3) the intellectual; (4) the aesthetic; (5) the practical. Even the then philosophers are said to be reluctant to do it. Also, it is not difficult to find that some of Greek virtues seem to be as much intellectual as moral. Thus, it is found in Homer that the hero of the Odyssey in pre-Socratic Greek, is an excellent all-rounder, who has a surpassing 'arete'. ('arete' implies respect for the wholeness or oneness of life, and a consequent dislike for specialisation; it implies a contempt for efficiency ~ or rather a much higher idea of efficiency, an efficiency which exists not in one department of life, but in life itself.) The Greek hero tried to combine in himself the virtues which "modern" heroic age divided, between the knight and churchmen.

> That the body is the tomb of the soul, is indeed an idea which is seen or met in certain Green mystery-religions, and Plato with his doctrine of Immortality, necessarily distinguished sharply between soul and body. (Kitto, 1951, p. 172)

As already shown, this is not typical of pre-Socratic Greek ideas. Indeed, every aspect of the pre-Socratic Greek life is manifested in the expression of "oneness" or "wholeness". In their physical training, which is regarded as an important part of education, it did not occur to them to train anything, but the 'whole' body. The availability of gymnasia, as well as theatres, and warships, has made men of all ages, use them not only for physical but also for mental exercise. Even when they made games part of their religion, (Olympic Games), the contests were seen as means of stimulating and displaying human 'arete' (quality of excellence). The poet Pindar, regards physical, moral, intellectual, as part of the one whole. In other words, there is a complete fusion of these parts which begins to disintegrate, following the writing of Euripides, twenty years after the death of Pindar, in which Olympic victors are seen as men of brawn and no mind.

6.3 MIND-BODY DIVISION

Up until the time when the early Greek philosophers emerged to wrestle with the problem of what is imperishable in the affairs of men, there seem not to be such things as mind and body, matter or object, form and substance. These divisions are just a dialectical invention that came afterwards. However, the modern mind still thinks that these divisions were there for the Greeks to discover. This is not quite correct, because they are just ghosts, immortal gods of modern mythos which appear to us to be real because we are part of that mythos. In reality, they are just as much an artistic creation as the anthropomorphic Gods they replaced. However, what is regarded as imperishable is within the domain of the Gods. With the growth of impartiality of the Greeks to the world around them, their power of abstraction which allows them to regard the old Greek mythos, not as revealed truth, but as imaginative creations of Arts strengthened. This consciousness had never existed anywhere in the world, and marked a step forward in the Greek civilisation.

The mythos continued, and that which destroys the old mythos, becomes the new mythos. The new mythos under the first Ionian philosophers have been transmuted into a philosophy which enshrines permanence in a new way. Permanence, ceases to be the exclusive domain of the Immortal God, because it can also be found within Immortal Principles of which the law of gravity is one. Thales refers to this Immortal Principle as Water. Anaximenes calls it Air. For Pythagoras, it is number, (the first to see the Immortal Principle as something non-material), and for Heraclitus, Fire and Change, are seen as part of the Principles. Heraclitus maintains that the world exists as a conflict and tension of opposites. According to him, there is "One" and there is "a many", and the "One" is the universal law which is immanent in all things. Anaxogoras identified the One as "Nous", meaning the "Mind". Parmenides, in his fragments B5 and B6, makes it clear for the first time, that the "One", "Truth", God, is separate from appearance and from opinion. The effect of this upon the subsequent history has already been stated. This is the point where the classic mind, for the first time, takes leave of its romantic origin and goes its separate way. Parmenides and Anaxogoras had Socrates as their listener, who later took their ideas and developed them to the full.

It is this idea of "wholeness", or "Oneness", which Heidegger exploits to make the point that technology is something that is not separate from man, and is not a neutral instrument science.

6.4 HEIDEGGER ON THE NEUTRALITY OF TECHNOLOGY

Not all aspects of Heideggerian philosophy are easy to grasp. He should be examined through the 'eyes' of Hood (1968).

By departing from the "narrow" traditional view of technology and claiming that technology is part of the existential structure of man and grounded in his being, Heidegger, needed to explain what he means by **man** and **being**. To achieve this, he introduces other concepts; some of these concepts include **"Being"** as fundamental, and belonging to the **"ontological"** dimension; **"being"** as phenomenal, and belonging to the **"ontic"** dimension.

6.4.1 BEING AND MAN

Man, in Heidegger's view, does not stand in some relation to technology. That is to say, technology is not something apart (external) from his being. It is grounded in man. Therefore,

> the relation between man and technology can be understood and the structure of technology fixed, only by coming to terms with the being of man. (Hood, 1968, p.352)

Accordingly, technology becomes meaningful by exhibiting its grounding in man's being along with the characteristics it receives from such grounding.

But what does man and being mean to Heidegger? Like all existential philosophers, he maintains that man is radically different from any object or thing, because he has a unique nature which can be known and understood only in terms of the intentional or oriented character which his concrete being expresses.

By denominating man **Dasein**, he draws attention to the basic link between man's existence and Being, and thereby indicates that man's very existence is what is proper to him and distinguishes him from other entities. But the noun Dasein, in German literally means, **'there-being'**. Man in his being expresses the actuality or the presence of Being. Moreover, because man performs his actions (expressing the actuality or presence of Being), from out of his inseparable context or world surroundings, Heidegger calls man **'being-in-the-world'**, to make the point that man's being or existence is the place where Being appears in the world. Since man is 'there' in the world and is the only being who is concerned with and actualises the presence of Being, Being can show itself only through man. Man is the only being to whom the world, including the things in it, e.g. nature, artefacts, and persons can reveal themselves in their own significance.

Due to man's relationship with Being, existence denotes a standing out from, or a coming forth or emergence of entities in their being. In other words, man himself, is **'being-in-the-world'**. The interpretation is that man's being is not that of substance, but rather a standing out from himself towards things, in such a way as to receive and express their significance. (Like abstracting one's self from something, or a situation.) By standing out from himself towards things, man becomes essentially a relating being.

This is unrepresentative of Heidegger's thoughts, in which he identifies man with the relation or (bond) existing between himself and things, rather than characterising man merely as subject and things as objects. In other words, man as **'being-in-the-world'**, represents the locus for subject-object relationships. The nisus or gap which separates, and at the same time unites, subject and object. That man is always in the world, is a basic fact. This presupposes that the disclosure of things and the one to whom they are disclosed, are co-original.

Plato and Neo-Platonistic philosophers, according to Heidegger, have systematically confused **'being'**, **'thing'** or **'entity'**, with **'Being'**. For Heidegger, **'being'** is that which is **'ontic'**, or phenomenal - anything which manifests itself, on this plane of consciousness, e.g. a tree, a molecule, an ideology or a person. **'Being'** on the other hand, is more fundamental than any particular **'being'** or phenomenon. However, in an ontological system, **'Being'** is not a supreme category, because it is neither a given entity nor everything in general. Thus, it can be said, that **'Being'** is the foundation for all entities and phenomenon. **'Being'** and **'being'** should not be confused or identified, because **'Being'** is the foundation of all **'beings'**.

As Heidegger asserts, conceiving something ontically (i.e. in its ontic dimension), allows one to grasp how it is related to other entities. But doing the same thing ontologically (i.e. in its ontological dimension), allows one to appreciate how it is related to Being. (i.e. to appreciate exactly how Being makes this entity possible.) Although both the ontic and the ontological dimensions are distinct, they are not separated. They represent the different dimensions of human existence as involved with entities. Man is thought to exist simultaneously in both dimensions. The ontological, though structurally prior to the ontic,

> it is not disclosed until after some entities have been encountered on the ontic level. (Hood, 1968, p.353)

In other words, because man exists in the ontological dimension, he is inclined towards an ensemble of entities such as quality, quantity, relation, etc. in the ontic dimension. But his background of ontological dimension, as provided by his basic orientation to Being, and the horizon of his ontic dimension, (which emerges from his discovery of entities), are revealed together. But Heidegger is decisive in maintaining that the ontic structures which are technics (tools), products, nature (power, materials) theory (science), inter-subjectivity, are a priori characteristics of man's encounter with things, and ontological structures are a priori characteristics of man. Ontic and the ontological are the two main characteristics of Being.

The relevance of what has been said so far, with respect to technology, is that Heidegger's conception of technology is not just in its ontic dimension (which is the activity of producing definite things with technics in characterisable ways), he also conceptualises technology, in its ontological dimension, (which is more fundamental). And it is by going beyond the instrumental conception of technology, an it be well understood. In other words, to grasp technology (even instrumentally), it must be understood as a way in which man comports himself ontologically towards entities - that is to say, technology must not be conceived ontically, it must also be conceived ontologically. By so doing one can see how man grounds technology and how it takes on its determination in such grounding.

6.4.2 FIXING THE STRUCTURE OF TECHNOLOGY (EXPERIENCE)

Consideration will now be given to how the ontological dimension of man makes possible the ontic determination of technology. In essence, how does this take place on the ontic level? According to Heidegger, the determination of technology on the ontic level (or the fixing of its structure) originates in man's transaction of ordinary experience. This structuring of ordinary experience takes place in terms of five ontic characteristics, namely, **TECHNICS:** (tools, implements, apparatus, machines); **PRODUCT:** (consumer and non-consumer goods); **NATURE:** (material and power); **THEORY:** (the role of science); and **INTER-SUBJECTIVITY:** (the social and organisation of labour). These five features represent the specific ways in which the ontological side of man's existence is realised through the creation of technology. By referring to technology as a total arrangement of technics, what is implied is that the five general characteristics of technology are made up of, or composed of, a complex structuring of ordinary experience, which is immanent to this experience. As the ontological dimension of man is actualised by the growing complexity of his transactions with technics, an increasingly definite character is given to ordinary experience. Technology becomes a dynamic structuring which grows out of, complicates, and pervades ordinary experience.

6.4.3 GROUNDING TECHNOLOGY ONTOLOGICALLY? (CONCERN)

Man grounds technology ontologically through the concept of, **concern** which defines his active relation to the world. **'Concern'** is man's relation to things insofar as this takes forms such as using, handling, production, etc. This concern for entities transcends man's specific nature and is directed toward all being. Inevitably, this widens the meaning of technology to include not only that it makes possible the execution and satisfaction of human needs, or that it is instrumental (both of which are correct), but also that which reflects the concern man has for the Being of entities. Technology then becomes ontologically possible because man's concern grounds it. In other words, man encounters entities by freeing them for their being.

Man, in Heidegger's terminology, is the clearing of Being. By his being basically oriented to Being, he is open to the given in experience. But as a relational being, he is partially at one with the given in experience by opening himself to it, as in turn, the given opens to him, and entities emerge. Put in a different way, what man experiences in the world depends on how he creates his world, how he structures it ontically.

> And how he creates the world, depends upon what he encounters in the world in his basic orientation, how the world shapes him in his fundamental possibilities. (Hood, 1968 P.354)

6.4.4 THE FIVE ONTIC STRUCTURES AND THEIR ROLE IN TECHNOLOGY

6.4.4(a) Technics

It must not be forgotten, that Heidegger is claiming that technology is part of the existential structure of man and grounding in his being. To support the claim, he describes the five ontic structures and their role in technology. And then demonstrates how man ontologically liberates or frees these five structures. However, it must be conceded technology begins with ordinary experience; in other words, ordinary experience is the locus for technology as well as anything else that has been created. Like all other experiences, technology is a development that grows out of ordinary experience. What is ordinary experience? Ordinary experience is the pre-reflective side of man's existence; it is his range of daily activities in the everyday world characterised by an indefinite pattern of transactions with things in his environment, an indefinite, extended pattern of doing and undergoing something, some place, some time with some thing. With reference to the ontic dimension of human existence, ordinary experience is the familiar, common mode of man's involvement with things: such as doing things in his surroundings, e.g. manipulating, using, consuming them, driving a car, preparing and eating a meal, etc., etc. The list is inexhaustible.

However, certain things are readily available to facilitate man's involvement with things. These things are ubiquitous that we are hardly aware of their familiar presence. These things define the first ontic structure of technology, namely, **technics:** artefacts created and used for human purposes. They are responsible for shaping ordinary experience through constructing a domain of well-circumscribed objects among which man moves. When man uses technics to do (or for) work, he finds himself located within a multiplicity of technics which stand out from a common background; his surroundings and the useful objects in it come to be contextual, i.e. emerge from a more or less unarticulated horizon. In every transaction with his environment, man comes across and utilises technics. In other words, transactions which man carries out in his environment, are mediated by technics. He is engaged with technics in ordinary experience no matter what the task is. Those entities which man encounters in concern, Heidegger calls equipment. Such that in our dealings, we come across and utilise equipment for writing, sewing, working, transportation, measurement. Thus, technics cover all artefacts which can be said to exist for something. Technics include more than tools; it includes things like machine, instruments, implements - anything which is for something. This conception of technic covers particular technics which are functional (such as a hammer whose handle has been broken). We have identified a technic any time we ask the question 'what is it for?' How then does a technics differ from simple material object? According to Heidegger, something is a technic when it is not ascribed to physical properties.

> For instance, to say that something is a hammer is not to impute physical properties to it, such as being blunt, having a certain hardness, or being made of steel. But from man's actual use of the hammer, it will be appropriate to ascribe relations to the hammer such as being used to pound in nails, straightening out metal securing shingles, being used skilfully, clumsily, rapidly. These relations make sense only in the specific mode of encounter with the technic in question; in other words, they are relations to persons, meanings conferred on entities for the sake of executing tasks. (Hood, 1968, p.355 -356).

Undoubtedly, technics have a physical existence. But this does not nullify the distinction between technic and material objects considered not from their utility standpoint. When we talk about technics, as being well or ill designed, convenient, handy or unhandy, suitable or unsuitable, we understand immediately that physical properties are not what is implied. Given this explanation of technic, our encounter with technic according to Heidegger, expresses itself initially in the form of an intention to bring about some definite transaction with our environment, as implied by the use of that technic. When a technic is taken and used by someone, it incorporates a projected transaction directed toward changing the environment, no matter how small or inconsequential the change might be (e.g. clearing the bushes for farming). Besides changing the environment in some ways, this transaction marks out the environment, and gives it, as well as the things in it, (the cutlass, the people using it , the coterminous surrounding) a context. A technic thus always opens some portion of the environment by referring beyond itself, something which is made possible by man's being-in-the-world. The being of man in its ontic dimension makes the creation of technics possible because of his concern with entities. The openness of technic, in turn, makes the creation of technics possible to objectify and discharge human purposes. So ontically speaking,

> ordinary experience is the forward thrust of man in things that is structured contextually by technics. Technics are incorporations and expressions of this forward movement, forming and stabilising such movement. (op. cit. p.356)

From what has been said so far about the nature of a technic, it is possible to say what is intended by referring to technology as a total arrangement of technics. It is simply, that technics are never used in isolation; they always occur as members in a context of technics. (i.e. a totality of tools, implements, materials, energies, and other items of use). Such context include science and persons. A total arrangement of technic might be a house, a carpenter's workshop or a factory. And to stress the spatial function of technic, Heidegger introduces the term **'contextual-totality'**, to describe the total arrangement of technic.

6.4.4(b) Product

Besides spatializing man's environment, contextual totality has another function which is to create a **PRODUCT.** Every member of a given contextual totality, i.e. all of the tools, materials, machines, energies and personnel, are directed to the realisation of some product or other. The product represents the final reference of the contextual-totality and comprises its unity as a pattern. Even if we have the entire technology of society as a total arrangement in mind, any given contextual totality belongs to a more inclusive one that is subsumed within an even broader one and so forth, until no final assignment or definite terms can be found. If this is the case, i.e. if there can be any final assignment in ordinary experience at the level of technics and products, then it is understandable that we may be tempted to relate technology to something external as the traditional concept did. Contextual totalities do not stand alone; they are mutually interrelated in man's transactions with his surroundings. Through the process of using technics to deal with entities, man experiences himself as the originator of his ongoing action and also as one who is the recipient.

6.4.4(c) Nature

The use of technics does not involve the manufacturing of product; for as they open our environment to disclose that it is a domain that contains more than technics and other kinds of artefacts, Nature becomes included. Technics mediate between man and Nature in ordinary experience. Through conceptual totalities, man is carried into the totality of human things called **NATURE.** And Nature becomes converted into technics and product. The conversion of Nature into energy and material has brought this about. The employment of technics necessarily refers to certain natural materials. Assignment for instance, are made by the shoemaker to leather, rubber, thread, nail and other material in manufacturing shoes. But the materials for work of any kind come from Nature and are rendered serviceable for that work. Patterns, forms and structural possibilities which are present in natural entities are released and incorporated into experience by the use of technic. They are potential factors in the manufacturing of projects and they originate from the material revealed in contextual totalities. Through spatializing his environment, man penetrates Nature, which is included within technology and at the same time is beyond technology.

Technology also encompasses Nature in the form of energy. And so nature is not only around man in the form of material, but also before man as energy. Nature offers direction for the execution of tasks; suggesting to man how he might make better use of his environment. Just as Aristotle's view of Nature is no longer acceptable to modern science, so too is the relationship between Nature and technology. Nature, within the contemporary view, has lost its formal character, as it has become elementary and abstract, capable of elaborate symbolic manipulation under highly special and artificial conditions, which can be given a multiplicity of forms. Thus, Aristotle's distinctions between matter and form, artificial and Natural things, become inapplicable. After all, an unequivocal conception of nature is difficult. Thus, what we see is some form of stipulative definitions adopted for the purpose of investigation; such as the definition of Nature as

> "the sum total of elementary forces and materials in the universe."
> (Hood, 1968, p.359)

6.4.4(d) Theory

Given the awareness of the relativity of our knowledge of Nature and of its dependence upon our somewhat specialised approach to it, and given the realisation that our knowledge is effective in solving technical and human problems and endowed with creative power, we begin to see the coming together of technology and Nature, making science. Thus, in this century, we have witnessed the effective and creative power of theory making possible many of the extensive changes which we find in such diverse areas as agriculture, manufacturing, communication and war. The development of modern science, together with that of technology, has caused a bridge to emerge from Nature to technology, connecting the potentialities of Nature with the possibilities of technology, --- something Aristotle and Plato would not have thought possible. Contextual totalities include **THEORY**. We are able to respond to Nature as something in its own right, because we spatialize our environment and realise that there are natural objects apart from objects for use. It is in theory that the technological horizon undergoes a profound modification. Here, the world of ordinary experience is changed into a theoretical conception of material objects. With technics, it is possible to undertake a theoretical study of Nature. But for the contribution of technics in the genesis of a technological horizon, within which the human can be distinguished from the natural, science would not be possible. The support for technology has come from science, following the realisation that the study of Nature can help man in dealing with his environment. As a new attitude toward Nature and technology developed during the nineteenth century, technology and science were united. A view of Nature as the storehouse of energy and indefinite supply of power and material waiting to be appropriated, became prominent, contrary to the Aristotelian view of Nature, as mentioned earlier. The engineers and the physicists see Nature as a **'calculable ensemble of forces'**. Indeed modern science, in Heidegger's view, did not arise merely because Nature demanded it, but because of a new conception of Nature as a complex arrangement of forces and energies. This allows experimental method to uncover them as they are. Clearly, the rise of modern science, not ancient or Aristotelian science, of theoretical physics, of experimental design, and of modern technics, has been as a result of the emergence of a new attitude, a new conception of man and his relationship to entities.

Both science and technology become perceived as means for the domination of entities taken as materials and stores for possible energies contrary to the traditional conception. The energies and possibilities released and amplified by science and technology are not merely accessories to human existence, not merely an extension of external capacity, but belong essentially to man's bringing Nature near. His openness makes possible the determination of the space of Nature. According to Heidegger,

> at the ontic level, both theory and production tend toward the functional manipulation and use of natural possibilities. Thus, science and technology are rooted in the same conception of nature, both arose out of the same horizon.

Interestingly, the distinction which Aristotle made between theory and making misses the integral connection between theory and technique. Technique, or making, is not an accidental but an integral feature of modern technology; technology includes science and technique. It is theoretical by nature. Indeed as implied by Aristotle,

> the union between knowing and changing the world, is far more intimate than the mere assignment of the fruit of theory to practical application.

Theory is dependent upon making, and making is dependent upon theory, both being identifiable strands of the experiment. Theory and technique show themselves in two different ways: (1) by means of the experiment, transactions are effected with Nature. Theory obtained in this way leads to, and renders possible, changes in application, e.g. nuclear physics through knowing nature creates nuclear reactors. In turn, the application of theory becomes a new source of knowledge not to be found in the laboratory alone. It furnishes new equipment for more effective experiments, which again yield new gains in knowledge, and so on, in continuous spiral. In this manner the dynamic union of theory and application, knowing and making, become inseparable in a way in which Aristotle thought impossible. Thus, technology encompasses both theory and making, a fact which cannot be accounted for by the traditional conception.

6.5 RYLE'S CONCEPT OF THE MIND

Gilbert Ryle's concept of the mind, wrapped up in his dogma of the **"ghost in the machine"**, is supportive of contemporary thinking, but fiercely critical of Descartes' mind-body distinction. He attempts to answer the question why is it that most people know how to make correct use of concepts which apply to mental activity but cannot state the logical regulations governing their use? In doing so, that he makes it clear that the problems which we have when we talk about mind-body problem, our knowledge of other minds, solipsism, etc., are rooted in the errors of philosophers. Of relevance here is the problem which modern European thinkers have in abandoning the idea of the existence of mind and body forcefully put by Descartes. As stated before, Descartes in his writings, implies that the mind dwells in bodies and shares none of the characteristics of material things.

According to Ryle, to think that the mind is a ghost mysteriously embodied in a machine (body), is to commit a 'category' mistake of confusing the logic of discourse about bodies and things, with the logic of discourse about minds. For example, to think that the University is an entity in the same sense that its component colleges, libraries, laboratories etc., are entities, would be to make a category mistake. Also to think that 'team spirit' has the same kind of reality that batsmen, fielders, umpires do, would amount to making the same category mistake.

Certain categories are used to describe the physical world. They are 'things', 'stuff', 'attributes', 'state', 'process', 'change', 'cause and effect'. The error which we commit, according to Ryle, when trying to theorise is to suppose, that there are 'things' called 'minds' comparable to things called 'bodies', and that there are mental 'events' like physical ones, which have causes and effects. To think of the mind in such terms is paramechanical. Mind in this fashion is regarded as immaterial, hence the term 'ghost'. It is believed to press levers, open windows, relieve shocks, exert reactions, much as if it were material. We also commit what Ryle regard as a 'category' mistake, when we teach, that the mind knows itself in a peculiar direct manner. This is a paraoptical view of self-knowledge, reinforced by the optical phenomena aspect of Galilean science, which has replaced the paramechanical hypothesis of minds.

For Ryle, there is no such 'thing' as mind. It is a solecism to speak of mind as knowing this or choosing that. The correct thing to say, is that a person knows or chooses. Some of our actions show qualities of intellect and character. And the fact that we know or choose, can be classified as a 'mental fact' about us. According to Ryle, it is an unfortunate linguistic fashion which leads men to say that there are 'mental acts' or 'mental processes' comparable to 'physical acts' and physical processes.

The error of talking as if there were a mind, is derived from our failure to distinguish different types of statements, and from supposing that what is characteristic of words in one kind of sentence is also characteristic of words in other kinds of sentences. For instance, words such as 'know', 'believe', 'aspire', 'clever', and 'humorous', are 'dispositional' words, according to Ryle. And in the statements in which they occur, they do not assert matters of fact, but capacities, tendencies, propensities, etc. So that you cannot say to a sleeping man that he knows Russian, and then affirm an additional fact that he has blue eyes and dark hair. Dispositional statements are similar to hypothetical propositions of modern logic. They are indicative sentences and may be true or false in the sense that they are verifiable under certain conditions. A man knows Russian if, when he is spoken to in Russian, he responds appropriately in Russian. But no one criterion of performance is sufficient. Ryle asserts, that in addition to 'dispositional words', there are 'occurrence words'. The latter apply to our high-grade activities, which may be called 'mental'. Driving a car, is an instance of occurrence, whereas, paying heed, is an instance of disposition. (A state of readiness.) The double-process which misleadingly suggests itself here, (with the bodily activity, e.g. driving a car going on more or less by itself and intermittent mental process trying to parallel what is going on in the body), is not two processes, but one. Thus, when we say, that a person heeds what he is doing while driving, we are making a 'seem hypothetical' statement. A heedful person drives differently, because he is alert to chance holes, pedestrians; but the heeding is not itself an act in addition to the act of driving; it presupposes no other agent other than one who is driving the car.

Moral and religious thinkers have been driven to assert the autonomy of the mind, following the successes of physical science, from the time of Galileo. Many theorists were excited by the expectation that the world might ultimately be explained, in terms of motion of the bodies according to laws which can be demonstrated mathematically. Of course, these moral and religious thinkers were interested in human freedom.

According to Ryle, the laws of nature are not 'fiats', i.e. authoritative, or warrants. Law statements are 'open' hypothetical sentences, i.e. sentences in which the conditional phrase contains a universal term such as 'any', or 'whenever'. Such sentences do not, like categorical sentences, affirm the existence of anything. 'Causal connections', for example, do not exist in the same sense as the existence of bacteria and the disease they are alleged to cause. Thus, statements about physical laws do not mention anything. they are merely predictive of behaviour.

Ryle puts forward the view that, instead of the mind, there is behaviour. However, behaviour frequently involves 'higher order actions' in which the second agent is concerned with actions of a first agent, as in spying or applauding. Our higher order acts may be directed upon our lower order acts, as in the case of self-criticism. According to Ryle, we will ordinarily refer to this as self-consciousness. This is unsympathetic with the motion of introspection, wherein we look into our own mind and discover its workings. In fact, when we do engage in the so-called introspection, according to Ryle's conception, we are engaged in retrospection, instead. Any attempt at introspection, i.e. to glimpse ourselves in the act of thinking, is hopeless. Clearly, Ryle rejects the claims of introspective psychology, based on the paraoptical model of knowledge. But he seems to accept the fact that we do know our feelings immediately. However, he carefully distinguishes feelings which are agitations, from moods and tendencies, which are dispositions. He maintains that for tendencies which are dispositions we have no immediate knowledge, only as they eventuate in actions, can we form any estimate of them. Hence, our knowledge of ourselves, come from our observing of our own behaviour.

6.6 THE UNITY OF "KNOWING-HOW" AND "KNOWING-THAT"

As technology is concerned with action, and knowledge, Ryle's concept of "knowing-how" and "knowing-that", becomes pertinent here. In line with the concept of unity of "mind and body" (or "knowing-that" and "knowing-how"), or knowledge and action for that matter, it may perhaps be helpful to examine some of the views about knowledge and action.

According to Powell (1967), three commonly held views can be discerned. The first view relates that when we are concerned with action, we are supposedly concerned with "knowing-how", and not "knowing-that". Polanyi (1967) seems to have expressed the same view in his assertion that technology teaches action. And, according to the second view, actions are supposedly explicable by reference to (or in terms of) rules, commands, prescriptions or imperatives; they are characterised by the fact that they are neither true nor false. The third view asserts that if actions are explicable by reference to matters of fact, then they are matters of facts about the agent (or individual), his desires, wants etc., and, in particular, the end which he desires to bring about. With reference to what might be regarded as the "standard instance" of an action explanation, there must be some beliefs on the part of the individual that there is a causal connection between his performance of an action and the attainment of his desired end. It is not very clear yet how relevant his beliefs are, in this case; for instance, what difference does it make if his beliefs are true or false? However, in reassimilating "knowing-how" to "knowing-that", it is assumed that, if some actions are to be explained by reference to matters of fact, then we cannot admit a radical distinction between some of the things people do, and some of the truths that they learn. (Powell, 1967, p.9).

Ryle's distinction between "knowing-how" and "knowing-that", seems to reflect this non-admittance of a radical distinction.

6.7 THE DEFENCE AGAINST INTELLECTUALIST LEGEND

The intellectualists' traditional view which distinguishes between the truth which people learn and the things they do, is summarised in Ryle's words,

> there are certain parallelisms between "knowing-how" and "knowing-that", as well as certain divergence.

The fact that in talking about things that people do, we say nothing about the truth which they learn, is implicit in the passage below:

> Theorists have been so preoccupied with talks of investigating the nature, the source and the credentials of the theories that we adopt that they have for the most part ignored the question of what it is for someone to know how to perform tasks. In ordinary life, on the contrary, as well as in the special business of teaching, we are much more concerned with people's competencies than their cognitive repertoires, with the operations than with the truths they learn. (Ryle, 1949, p.28).

Ryle in his book argues that there are no internal acts of the sort put forward by the intellectualists going on during the performance of an act. The verb "know" does not indicate occurrence. For reasons put forward by Ryle and Ayer, to say that a person knows, is not to say that he is performing an inner act. Apparently, his (Ryle's) response has been on the consequence of the intellectualists view, namely, the separation between theory and practice, or that the mind thinks and the body responds accordingly. The usage of the epithet "intelligent" to describe an action is nothing but a reinforcement of this view.

The epistemologists (like others) have always fallen into the trap of expecting dispositions to have uniform exercises. By recognising that verbs such as "know", and "believe" are ordinarily used dispositionally, the epistemologists then assume that there must, as a consequence, exist one-pattern of intellectual processes in which these cognitive dispositions are actualised. For example, if you believe, that the earth is round, you must from time to time be going through some unique proceeding as cognitive, judging, or internal re-asserting with a feeling of confidence that the earth is round. (Ryle, 1949, p.44)

Briefly put, the intellectualists' position is that actions are classified as "intelligent", only if they are preceded by an internal act of theorising, and that it is this internal, anterior performance which earns the action the title of "intelligence". In other words, an action is said to be "intelligent" when the action is carefully or skilfully executed, i.e. when it is performed in a thoughtful manner. Such that acting rationally, means

> having one's non-theoretical propensities controlled by one's apprehension of truths about the conduct of life. (Ryle, 1949, p.26).

Proponents of intellectualist views then try to reassimilate "knowing-how" to "knowing-that", by saying that intelligent performance involves the observation of rules, or the application of criteria. (Which in some sense describes performance in technology). It then follows, according to the proponents, that the operation described as intelligent, must be preceded by an intellectual acknowledgement of these rules or criteria. In other words, the person performing the operation must first go through the internal process of avowing to himself certain proposition about what is to be done ('maxims', 'imperatives' or 'regulative proposition', etc.) and only then can he execute his performance in accordance with those criteria or rules. According to Ryle,

> he must learn to preach to himself before he can practice. The chef must recite his recipes to himself before he can cook according to them; the hero must lend his inner ear to some appropriate moral imperative before swimming out to save a drowning man; the chess player must run over in his head all the relevant rules and tactical maxims of the games before he can make correct and skilful moves. To do something thinking what one is doing is, according to this legend, always to do two things; namely, to consider certain appropriate propositions, or prescriptions, and to put into practice what these propositions or prescriptions enjoin. It is to do a bit of theory and then do a bit of practice. (Ryle, 1949,).

As already stated, Ryle rejects this intellectualist view, on two important grounds. The first , that to perform intelligently does not require prior internal performance. And the second is that the class of intelligent performances is much wider that that allowed by traditional philosophers.

Expounding his first objection, Ryle points out that to posit an internal act of theorising before performance, results in an infinite regress:

> The crucial objection to the intellectualist legend is this: The consideration of propositions is itself an operation the execution of which can be more or less intelligent, less or more stupid. But if, for any operation to be intelligently executed, a prior theoretical operation had first to be performed and performed intelligently, it would be a logical impossibility for anyone ever to break into the circle. (Ryle, 1949, p. 138)

Regarding the second of his objections, Ryle points out that there exist a lot of classes of performance in which intelligence is displayed, but of which the rules or criteria are not formulated. Thus, if there are no rules or criteria for such performance, then there cannot be prior act of considering rules or criteria.

> The wit, when challenged to cite the maxims, or canons, by which he constructs and appreciates jokes, is unable to answer. He knows how to make good jokes, and how to detect bad ones, but he cannot tell us or himself any recipes for them. So the practice of humour is not a client of its theory. The canon of aesthetic taste, of tactful manners and of inventive technique exercise of those gifts. (Ryle, 1949, p.137)

Many performances, which cannot be defined in terms of the apprehension of truth, may be counted as intelligent. For instance, making and appreciating jokes, making and appreciating pictures, the tipping and tumbling of a clown, are but few examples. That Ryle equates these performances as "know-how", is even open to question.

Intelligent performance should necessarily be what is performed intelligently. However, that many philosophers have tended to define all other mental-conduct concepts in terms of the cognition, the verb to "know" is, after all, such a concept. It is clear that intelligent performance has been unduly restricted when intelligence is defined in terms of cognition. This is not to suggest that the concept of cognition should be stretched to cover all intelligent performances. According to Powell (1967),

> it is either necessary to provide some justification for using a concept of cognition in connection with the wit, who is said to "know how" to make good jokes and how to detect bad ones, or misleading to use a word like "know" in spheres where questions of truth appear to be irrelevant. To grant that there is no intelligent performance which requires an internal act of apprehending truth is not to grant that no intelligent performance requires to be understood by reference to truth. (p.23)

Powell is, in effect, saying that we should not use the term "know" indiscriminately to describe actions as intelligent. Such usage of the term should be restricted to actions, of the kind to which reference to truths is required.

Truths can be established and learned about through such actions as bridge building, plumbing, gardening, cooking, installing telephones and electricity, sailing ships and launching rockets. But there are no such truths to be established and learned with respect to actions like making and appreciating jokes. If imposing such restriction, would constitute a problem, then, at least the distinction between actions of the kind which truths are relevant and those to which rules are not relevant (e.g. making and appreciating jokes which have no truths or rules or maxims) should be made.

Nevertheless, to use the word "know" to describe any action as intelligent without due consideration of the kinds of criteria which are involved, may result in it becoming vacuous. Thus, there will be no reason why we cannot talk about moral or aesthetic knowledge, provided we are prepared to call it "knowing how". Whereas there can be medical knowledge on the grounds that there are medical truths, there is no moral or aesthetic knowledge, since there are no aesthetic truths.

The idea of getting something right, also applies to the actions performed by people. Intelligent performance, is regarded also as one in which the agent applies criteria in performing: i.e. tries to get things right. Apart from there being the questions about what it is to apply criteria, there are questions also about the nature of the criteria being applied. These criteria or standards are independent of the agent, just like the criteria by which we judge that one is right about the state of the ice, is independent of one, i.e. one's behaviour. However, the criteria for some right (intelligent) performances, are not necessarily to be elucidated by reference to certain sorts of truths. For instance, the criteria for the hero who swims to save a drowning man are not to be understood in terms of certain sorts of truths. And a distinction is needs to be made between knowing-how to tell the difference between a chalk and cheese, and knowing-how to tell the difference between a bad and good joke. Although intelligent performance does not have to be preceded by internal acts of theorising, there is still the need to make the distinction between different kinds of intelligent performances.

6.8 KINDS OF INTELLIGENT PERFORMANCES

The individual's knowledge of certain truths and his ability to do certain things, has been distinguished using the epithet, "knowing-that" and "knowing-how". Surely there is a difference between having mastered the theory of driving a car and actually being able to drive a car. One may know all the relevant facts about say, installing telephones, but be unable to perform such a task. What is implicitly invoked here, is the point about the conditions for knowledge. A necessary condition for someone to be said to know p, is that not only that p must be true and that he must believe p, he must also have evidence for the truth of p. To make the conditions of knowledge very high, sometimes what seems to be meant, is for one to be able to cite the evidence by which p is established as true. This amounts to nothing but the expounding of theory of, say, telecommunication, and it is unrealistic to suppose that the person who is able to expound theory, really "knows". Nevertheless, to suggest that the person who cannot expound a theory but who can install a telephone also knows, is to make the condition for knowledge more flexible.

It seems misleading to assert that it is possible to know a person merely from his overt behaviour. Mainly because not all the things which a person performs, in the sense explained above, can be regarded as exemplifying knowledge. That a person knows something can be denied on the grounds that this is not the kind of thing which can be known: e.g. the difference between right and wrong, or good and bad paintings. However, the difference between knowledge of certain truths and having an ability to do certain things is not so great as we have been invited to believe. Furthermore, the possession of a skill does not merely depend on what one does, but on what one does correctly, and rightly.

6.9 SUMMARY OF "BROAD" (CONTEMPORARY) VIEW OF TECHNOLOGY

Remember, it is the distinction between mind and body, in which the former is superior to the latter, that has led to the dismissal of technology as a form of human knowledge. Both Heidegger and Ryle in their exposition have argued, that the philosophical basis on which technology is dismissed as a form of human knowledge is naive. Both of them have favoured a philosophical basis which presupposes the unity of "mind" and "body".

The foregoing exposition has identified a tradition which is different from the Plato-Aristotelian one, which, after two thousand years has been left behind. However, what this exposition has clearly shown in effect, is that what happened before Plato in terms of thinking about phenomena, is in tune with what is happening nowadays. Of equal importance, is the acknowledgement of the concept of technology as a form of human knowledge.

6.9.1 THE IMPLICATIONS FOR PSYCHOLOGY OF TECHNOLOGY OF THE TWO PHILOSOPHICAL VIEW POINTS ABOUT TECHNOLOGY

Before examining the extent to which this "broader" philosophical view of technology has influenced schools' approaches to the definition of technology, it is vital that the implications for the psychology of technology of these two philosophical views of technology be considered.

The main concern of this investigation is about the psychology of technology, not philosophy of technology. Thus, it makes logical sense to examine the consequences for the psychology of technology of the two philosophical viewpoints presented here, so that the "broader" philosophical view point for which this investigation shows sympathy, can be seen in its proper context.

It is not out of place to suggest that the "narrow" philosophical conception of technology, has elements of, or can be identified with, Cartesian tradition, because the importance of technology is downgraded. Piaget, to a large extent, is in sympathy with this tradition. Although, as a rationalist he talks about action, etc., his is not into technology. Indeed, technology is not important in Piaget's scheme, science and mathematics are important instead.

Rationalists do not accept that knowledge is knowledge of this physical world. They maintain that because of the changing nature of this world, it cannot be known, or be the proper object of knowledge. Thus practical experiments cannot provide absolute knowledge.

The consequences of this philosophical viewpoint for the psychology of technology are far reaching. By implying that mental states are produced by physical and chemical changes in the body, descriptive psychology finds it difficult to function as it should. It may be that, a better understanding of this point will be attained by considering the psychological implications of the "broader" conception of technology.

The "broader" concept of technology which incorporates Heidegger's conception, sees the rationalist tradition, for which Piaget shows sympathy, as inadequate. Within this "broader" philosophical view, technology is positively evaluated and regarded as an activity involving a combination of knowledge and action.

Within Heideggerian tradition, knowledge of the physical world is implied where reference is made to knowledge. Technology, as a form of human knowledge etc., is concerned about things that works in this world, and thus, knowledge of the physical world is understood.

What the above paragraph is suggesting is that the conception of technology, within Heideggerian tradition, lends itself to descriptive psychology, that is, the description of mental states themselves accurately through the process of self-examination and analysis. This is something which is missed by taking the rationalist view of technology.

Due to the fact that actual reaction to phenomenon is important, Heideggerian conception has become the foundation for phenomenology.

CHAPTER - 7

APPROACHES TO DEFINING DESIGN & TECHNOLOGY IN SCHOOLS

7.1 INTRODUCTION

Thus, an understanding of Design Technology in which the essence is seen in the fact of methodological characteristics of the procedures employed, and in the fact of human activity, seems to correspond to the usual (or today's) meaning or understanding of it. In other words, the conception of Design and Technology as a purposeful activity, a process and a form of human knowledge, appears to be in tune with today's understanding of it. What this means in effect is that to attempt a good description of technological thinking will require such an understanding of technology. This understanding is implicit in, the definition of design and technology for schools' use by the National Curriculum as shown below.

7.2 DESIGN & TECHNOLOGY: SCHOOLS' DEFINITION

According to the National Curriculum document, Design and Technology is defined as the pupils' 'capability through combining their design and making skills with knowledge and understanding in order to design and make product, (DFEE 1995, p.2). Earlier definitions also had these characteristics. However, between the time when the momentum for the inclusion of technology as one of the areas of learning and experience in the secondary school curriculum which should feature in a rounded education, was gathering strength as from the early 1960s and its apparent full acceptance in the 1980s, (DES 1985., Dodd 1978), numerous and indeed different definitions had been expressed to reflect the two 'complementary' framework of conceptual definition of technology mentioned earlier. A few of these views will now be considered. It has to be noted, at this point, that some of these views have inherent difficulties.

Black and Harrison (1985, p.3), regarded technology as the

> practical method which has enabled us to raise ourselves above animals and create not only habitats, food supply, comforts, ... but also our arts, music, painting, sculpture, literature.

It is true to say that, without food technology, it would be difficult for us to have painting, sculpture or literature.

What Black and Harrison's definition does is to lump together an awful lot and attribute it to technology. For instance, securing food supply is a technological process, in a way in which securing painting is not. Certainly, one can make a strong claim for technology in relation to food supply, but a weak claim for technology in relation to painting. Thus, it is not too difficult to see that this definition seems to be fraught with difficulties. These difficulties are, however, less apparent in Gradwell and Welch's, definition (1983) wherein the fact of human activity is underlined. They accordingly assert that

> ....the use of technology involves mankind linking technique (consisting of the laws of science and a knowledge of how things work) and action. Action in this context, refers to the process of creating new systems: new tools, machines, processes, information and eventually techniques. .....technology is the skill of inventing, designing, planning and problem solving ..... the process of technology. ....technology is a uniquely human activity, that it comprises an ever expanding body of knowledge and that it is a dynamic and pervasive force within society.

This seems to embrace the principal ways in which technology ought to be conceptualised.

The definition put forward by Quebec Ministry of Education does not appear to do justice to man's creative urge to explore more and more through technological advances, but to emphases the methodological nature of the procedure involved. It defines technology in a number of ways for a Quebec-based Introduction to Technology course:

> from a historical point of view, technology may be defined as a study of manufacturing process, a study of industrial operations carried out in the light of the result it is proposed to obtain. In its general sense, technology may be described as an art which borrows certain principles from the exact sciences and which examines existing objects in order to

> design new ones which will fulfil well defined needs. ... as an element of education, technology is considered to be the outcome of a more or less lengthy process which originated in a need that could only be satisfied by technical means and whose outcome is undetermined. .... necessary for human sustenance and comfort.

It appears that this definition goes beyond what it says, to make life very uncomfortable for human sustenance. For example, building a rocket to go to the moon might have a long term aim of improving comfort, but man's creative tendency to explore more and more is not given any attention. With this definition, the tendency is to push the frontiers back through technology, rather than just providing for sustenance and comfort. It is like saying that technology is home economics. It is self implosive, not dynamic, but progressive.

Although the rest of the definitions do not carry with them serious unjustifiable assumptions, they either stress the fact of human activity in technology or the methodological characteristics of the procedure involved.

Thus, in HMI's view, technology is concerned with meeting people's need or purpose; the controlling of the environment; the application of scientific and other resources; the creative process of using human knowledge and physical resources to solve practical problems.

According to Page (1982),

> technology is the process by which people cope with their environment. It is therefore a problem solving process which has as its start, human need and as its goal, human achievement, and as its continual companions, the resources and restraints of human knowledge, human skills and the world's natural resources.

And for Allsop et. al. (1982), it is

> a disciplined process using scientific and technological concepts and materials to achieve a human purpose.

This is another attempt to bring together the two complementary frameworks.

For Roy (1978),

> ...... technology is .... the activity of applying organised knowledge to the development of tools, products and processes for human purposes.

The acknowledgement of the process component of technology is apparent here. Morris (1977) sees technology as

> "the application of science to achieve a practical goal or purpose".

Whereas Kestenbaum (1975), thinks

> ".....technology ..... meaning the application of scientific knowledge to serve social requirements."

These two authors are implying that technology is based on scientific knowledge, as well as other forms of knowledge.

According to Watkins and Meador (1977) technology

> ..... systematizes and applies practical knowledge for the benefit of man. Both of these authors see technology in terms of its methodological procedure, and of course implicitly stressing the natural systematisation of human activity.

Marshall (1975) thinks that

> ..... an activity which seeks to find optimum solutions after considering alternative possibilities. .....is a social rather than an individual activity ..... its roots are in the satisfaction of human needs, ... Technology acts in a social setting and has profound consequences for this material, social and moral environments.

Attention is focused here on an important dimension of technology which has not been mentioned. It is technology as value- or context-determined. Technological activity is not limited only by its knowledge base, unavailability of materials, etc.; it is also limited by those whose purpose it serves, and the context in which its outcome is to be used.

The Encyclopaedia Britannica (1974) catalogues technology as

> the systematic study of techniques for making and doing things.

> This means or activity by which mankind seeks to change or manipulate the environment.

In so doing, it endorses the methodological characteristics of the procedure involved in technology. For Suspend (1973) technology has to do with

> "....... man's efforts to satisfy his material wants by working on physical objects......."

This view does little justice to man's creative ability. In Hamilton's view (1973) technology is

> "... the means by which man extends power over his surroundings."

There is a mystical overtone here. Man should be working in harmony with his surroundings because he is a part or product of it. This view seems to alienate man from his surroundings. Accordingly, De Bono (1971) thinks that,

> "technology is the process of producing something useful through the application of knowledge."

Implicit in this definition is problem-solving. Harrison (1970) regards technology as

> "the disciplined process of using scientific, material and human resources to achieve human purpose."

This is a comprehensive way of saying that technology has to do with problem-solving here and now. By underlining the creative element in man through the process of design, Deere (1969) asserts that technology is designed.

> to meet a need ..... being concerned overall with the optimum rather than the unique. The two are brought together in what I will call the design triangle .... common to technology in any era, and in any field. The proposition is that there are three basic decisions to be taken, ... each of the three decisions is influenced by the other two, ... The three decisions are these: (1) choice of material .....
> (2) determination of shape and form ....
> (3) selection of method of achieving

form .
.....this design triangle is the very heart of technology.

The Concise Oxford Dictionary definition is:

> ..... theoretical knowledge of industry and the industrial arts; a discourse or treatise on an art or arts; ... the scientific study of the practical or industrial arts; ..... the science of the industrial arts.

In both views, there is an emphasis on "practical".

The definitions offered so far tend to bring together these two complementary frameworks.

7.3 MODELS OF DESIGN PROCESS IN SCHOOLS' TECHNOLOGY

However, of importance from these different views (see appendix-11c), is the almost concurrence that technology within the school curriculum, (a) involves a creative problem solving process. (The activity of applying organised body of knowledge); (b) utilises resources including capabilities and human awareness. (A body of organised knowledge); (c) achieves human purpose. (The product of organised knowledge).

However, it will therefore appear that no matter how one defines or conceptualises technology, underlying these attempts is the idea of bringing about change or exercising control over the environment. A process which is considered to be a particular form of problem-solving, of designing in order to effect control. In fact, this process is common to all technologies, whether they be concerned with the provision of shelter (building construction technology), food (agriculture), clothing, health and communications, or so called high technologies such as electronics, bio-technology, fuel extraction etc., or 'alternative technologies'.

7.4 THE TWO PRINCIPAL DIMENSIONS OF DESIGN

The various stages of design process cited represent the iterative (horizontal) dimension of design. This particular dimension provides the basis for the structure, which allows for imaginative response and logical thought. It also gives rise to the idea of design as a plan, scheme, an outline, or a plot or intention, which is formulated in the mind prior to actual execution. (Dodd, 1978, p.52)

It follows logically, that the other dimension, namely, the morphological (vertical), represents the progression of design from abstract to concrete. (Asimov, 1974).

In other words, the various stages of design process mentioned earlier, viz., invention (research development), design, making (production and construction), using (operation, sales and management), are characterised by conceiving (thinking in abstract terms), imaging (thinking in concrete or spatial terms), fabrication (thinking with one's hands/construction), testing (operation and observation of discovery).

7.5 DESIGN AND INTELLIGENCE

It has already been shown that "purpose" is implicit in technological design. There cannot be purpose without thought. This suggests the presence or use of some intelligence, and the vertical dimension of design points to this. The indication here is that at the strategic level, this design process necessitates the exercising of intellectual and motor skills. After all, any time we design something, we seem to use certain thought processes, and then manufacture our artefact to see whether in fact our design is valid. (STEM, 1981, p.68)

Obviously, with reference to technological designing, design is started whenever a need or a problem has been identified. A designer then works towards a solution using his or her experience and simultaneously keeping in mind the tools and materials available. (A designer here can be anybody, from a housewife thinking about how to arrange her kitchen for easy access, to the professionals e.g. architect).

Emphasising this intellectual dimension of design process, Dodd (1978) quotes Alyward (1973, p.43) as suggesting that

> design ...... is a form of control which can only exercised provided individual s have acquired the necessary knowledge and understanding.

And Alan (see Dodd, 1978, p.43) argues that in addition to the emotional response, participation in design requires,

> "a skill to identify and understand problems; to sift information and represent reasoned argument."

Pemberton adds

> in all, individuals will require the ability to obtain and analyse information; to form judgements and make assessments.

Bloom (1956), sums up the process of design in his taxonomy of educational objectives in describing the process of growing intellectual maturity:

> What is needed is some evidence that the students can do something with their knowledge, that is, that they can apply the information to new situations and problems. It is also expected that students will acquire generalised techniques for dealing with new problems and materials. Thus, it is to be expected that when the student encounters a new problem or situation, he will select an appropriate technique for attacking it and will bring to bear t he necessary information both facts and principles. This has been labelled 'critical thinking' by some, 'reflective thinking' by Dewey and others. In the taxonomy we have used the term 'intellectual abilities and skills'. The most general operational definition of these abilities and skills is that the individual can find appropriate information and techniques in his previous experience to bring to bear on the new problems and situations. This requires some analysis or understanding of the new situation; it requires a background or knowledge or methods which can be readily utilised; and it also requires some facility in discerning the appropriate relations between previous experience and the new situation.

It is obvious, that the bringing together of skills, experience, knowledge, understanding, imagination and judgement, in the execution of a specific task, represents the dominant feature of activity in the area of technological design.

7.6 TECHNOLOGICAL DESIGN

It has to be made quite clear here that, having acknowledged design as providing a means whereby knowledge can be applied, and therefore central to technology, 'technological' design, as opposed to artistic design is particularly implied. To understand technological design, and indeed technology, requires a grasp of technological concepts, which are grouped into control, energy, and structure. (These make up the knowledge structure in technology).

Technological concepts are essential in any design and technological activity, if those engaged in it are to be able to make design decisions, as well as to think, plan and express themselves in three dimension. (STF, 1977). These concepts have to be intellectually grasped sufficiently enough to be used for design decision-making purposes. Thus, technological concepts such as

> loan, strength and structural stability; energy transfer, efficiency, engine stability, mechanisms, open and closed loop control systems, hydraulic, pneumatic and electrical systems, sensors and transducers, amplification, display systems; materials and their choice for structural purposes; communications, modulation, transmission and reception; optical instruments, elevation in drawing, etc.(STF, 1977, p.11)

are evidenced in technology curriculum. Their use in practical design, distinguishes the technological designer from the artist engaged in three-dimensional art. If anything, as will be seen later on, design and technology curriculum reflects these skills and concepts.

7.7 DESIGN AND TECHNOLOGY CURRICULUM IN - SCHOOLS (THE NATIONAL CURRICULUM)

7.7.1 Brief Historical Development

In 1988 Design and Technology became the only new subject in the Curriculum. It was looked upon favourably by the politicians, notably the Prime Minister, Margaret Thatcher and Kenneth Baker, as a significant element in a technological revolution that would transform British industry. However, the new subject was expected to bring together a number of divergent traditions. It was not to relate spectacularly to gender, yet, had to incorporate well-established (but very different) subjects ranging from Metal-work and Motor Vehicle Studies to Home Economic Studies and Needlework. The new subject was also expected to cover the emerging area of Information Technology. However, faced with a vast range of potential content and few common skills, the first Working Group analysed the technological process. Our model was adopted, which moved from identifying needs; generating designs; their planning and evaluation.

The thought behind this model was that planning and cooking a celebration meal for a family involved the same processes as the design, development and retailing of a wall-bracket for a bookshelf. This is the version of the order as from 1988 until November 1994, on which many of the GCSE's Design and Technology syllabuses were based. There were four attainment targets (Te 1 - 4), which made up Design and Technology Profile Component (PCI). These were equally weighted. Information Technology (PC2 and Te5) was a separate profile component and attainment target. This curriculum was abandoned because of the tests that were planned for Key Stages 1, 2 and 3. Due to teachers' boycotts and disruptions, Ron Dearing advised that the National Assessment should be limited to the core subjects. As teachers were suddenly expected to offer a new subject to unfamiliar groups of pupils in many schools; they had to tear out heavy-craft facilities and replaced them with computer rooms or bright new workshops. Indeed there was a genuine confusion at this stage about the substance of the subject. Apart from inadequate availability of resources due to the extension of design and technology to all pupils, the emphases on assessment and testing by the government meant that class-room practices (that is teaching) had to take a secondary position. Blue Peter-type curriculum where cards, plastics and sellotape replaced wood, metal, fabric and food emerged thus proving difficult to assess. The Statement of Attainment was set beyond the capabilities of the pupils. The application of sound practical skills was stifled by the need for a lengthy process of writing to define a market, compare designs or evaluate the usefulness of a completed project.

By mid 1992, a decision was taken to revise the Design and Technology curriculum; this was assessment-led, being based on design and making tasks (DMTs). By the end of 1992 the revision was overtaken by the influence of Ron Dearing in 1993, who settled proposals made the programme of studies (POS) instead of Design and Making Task (DMTs), the dominant feature. This represented the starting point for the review. The Statement of Attainment was severely cut, and the outcome represents the final National Curriculum document, which is now the predominant curriculum of Design and Technology.

7.7.2 Summary of the New Design and Technology Curriculum

The new Curriculum came into force at Key Stages 1 and 3 in September 1995. The new GCSE syllabuses were published in January 1996 and introduced in September 1996 for examinations in 1998. The new attainment targets are abbreviated as AT. At Key Stages 1 to 4, there are two attainment targets **Designing** (AT-1) and **Making** (AT-2). At Key Stages 1, 2 and 3, there are no statutory requirements for assessment other than that teachers must report on achievement to parents at the end of the school year.

7.8 CONTEXTUAL ANALYSIS (DESIGN AND TECHNOLOGY)

A quick look at the sample of a technology syllabus used in schools England and Wales would reveal the kinds of principles of analysis and interpretation being asked of students, when they are engaged in the activity of designing, making, testing, (manipulation), communications and evaluation.

Admittedly, technology involved making things for use. The process of producing something for use is an involved one, and the details vary with the article e.g. from transistor radio through large dam, to space vehicles. But certain steps are common to all technology subject. Consideration of the possible courses of action and the selection of the course of action, are really the important steps. (Francis 1961).

The creativity involve in the process of producing something requires powers of synthesis as well as those of analysis. The ability to synthesise is more important, than the ability to analyse. It could be hardly disputed, that the majority of the tasks fulfilled by technology have been through a synthesis of elements which have physical character (some of which were thermal, mechanical, and electromagnetic), as well as devices of chemical and bio-chemical properties. Synthesis presupposed analysis. Every synthesis of elements presupposes that to a certain degree, knowledge of their causal relations and properties be known. In other words synthesis presupposes a certain level of knowledge of causal relations and properties. Logically as the task of synthesis became more complex higher levels of knowledge of causal relations and properties became necessary.

In technology the problems to be solved usually were more variables than equations, and the relationships were more of inequalities than equations: for instance, cost to be less than so much: working load not to exceed a certain value: loads likely to be less than so much. This can be likened to linear programming. However there were some variables which were non-numerical and could not be represented by mathematical symbols. These variables include aesthetic and sociological considerations. As this part of the technological problem had no unique solutions many comparable merits existed, and the decision about the appropriate one called for judgement.

7.8.1 Manipulation Activity

Schools' design and technology curriculum was not necessarily about designing and making, it was also about manipulating objects or systems. In the teaching of technology subjects, pupils might be required to manipulate, for example, dimensions, (as in technical drawing, architectural/building designing), or systems (as in electrical/electronic and mechanical engineering subjects, eg. fault tracing etc.) This was a feature which was not very difficult to find in the various aspects of the technology syllabus.

For instance, manipulating dimensions, such as shape, size, colour, solidity etc., was typical in technical drawing (Design and Communication, now termed Graphics), and to a greater extent, in Design and Realisation. Some of these dimensions were related, and others were not so related. In any case, their manipulation, was in terms of isolating, juxtaposing, categorising and combining. The mental ability involved in doing such tasks included perceptual discrimination, categorisation or setting up classificatory concepts. The pupils in effect used these abilities to relate the concepts or principles mentioned above to tangible things, such as house, tables. Similarly, in engineering (control) subjects, such as electrical/electronics, mechanical engineering, (Technology), which was concerned with controlling systems, the same thing was found happening during the early stages of learning these subjects. The introduction of the component parts of a system, and their various functions in relation to the whole system, feature prominently during the early stages of learning engineering subjects. In circuitry for example, where there was a range of components such as transistors, capacitors, reactors, etc., each one having more than one related concept, e.g. electrification, and amplification; in the case of capacitors and transistors respectively, the pupils had to learn, as beginners in an engineering technology course, to relate the appropriate concept to each component, in terms of its particular function in the circuit as a whole. This required the same mental processes as those described above.

Manipulating a system, say, a piece of equipment, so that it successfully achieves a particular goal, was also part of technological activity. The realisation of such a goal might also involve assembling, disassembling, operating, maintaining, trouble-shooting or a combination of these procedures. Larson et.al. (1986) pointed out that an understanding of the structural and functional relationships of the components of the system was necessary in order adequately to perform tasks which involved the manipulation of a system. In other words, the pupils must know (or learn) the parts of the system and how they interacted spatially and functionally. For instance, to trace a fault in a piece of equipment such as the oscilloscope or in an electrical/electronic system of, say, a motor car or electrical circuit, required that the pupils should know the characteristics of each control knob, their location and spatial arrangement, the names, functions of each control and the interrelationships between the controls. However, each of these control knob or components of the system, has one or more related (functional) concepts. What the pupils had to do during fault-tracing, or testing, (or manipulating a system), was to relate appropriate concepts to each component within the system.

7.8.2 Manipulation Tasks

In manipulation activity in technology where pupils were required to rotate images, assemble them, change colour, texture, or form, the importance of spatial ability or relationships in facilitating this task had been underlined. Indeed, the high scores on spatial ability tests by engineers and scientists, have not only served to distinguish them from other students, but have served to remind us about the link between technology education and spatial ability and achievement in science, for instance, which has been well documented. Physical science students have shown a consistent pattern. They were frequently shown to have greater spatial ability than the Arts, Social Science, or Biological Science students: (Lewis, 1964), (Hudson, 1964), (Butcher and

Point, 1969), (Bradley, 1981), (Smithers and Collins, 1981). The evidence pointed to the fact that spatial ability could be nurtured or acquired, rather than being a natural trait. In this respect, whereas Blade and Watson (1955) reported a significant improvement in spatial scores among male engineering students after a year's study, similar improvement was reported by Brinkaman (1966) after three weeks of training both boys and girls in elementary geometry. Bishop (1973) added to this body of evidence by reporting that primary school pupils who used structured apparatus in mathematics performed better in spatial tests than children from other schools.

7.8.3 Spatial Ability Task

Mere observation would show that spatial ability tasks varied considerably with respect to the thought-processes and skills required. For instance, embedded figure tasks deployed the ability to ignore a complicated or confusing background. Other tasks, however, required subjects mentally to manipulate two or three dimensional figures. IQ tests, e.g. AH4 and AH5, quoted by Heim 1968, 1970), do have items, described as 'spatial', which require the ability to see relationships between patterns, and not items that involved mental rotation or visualisation. The items in Raven's Progressive Matrices (1956) could be similarly described. Therein, the subject noticed the pattern of changes in a series of diagrams so that he could select the next from a number of possibilities.

7.9 CREATIVITY IN DESIGN & TECHNOLOGY AND ITS ASSESSMENT

Technology knowledge has a tacit dimension which is inaccessible to formal academic studies, but which is transmittable by personal contact. Attempts have been made to systematise this personal knowledge involved via studies in the area of creativity. (Bolton, 1972, p.205). Given the fact that technology has creativity as an important element, there exists a body of knowledge about the kinds of traits involved in individuals recognised as likely to produce novel and original solutions to the multifarious problems. This body of knowledge relates that some of the traits are best described as thinking skills or strategies, often identifiable as intellectual abilities such as convergent and divergent production. Others include the nature of personality characteristics; motivational category such as needs, interests, and attitudes. In considering the broader conception of the nature of intellectual ability, Guildford (1950, 1954) in the USA, and Hudson (1956, 1958) in the UK, have suggested that that 'effective' thinking (in this instance as applied to design technology subjects), would have two complementary characteristics:

> first the capacity to range flexibility or diverge, in search for the relevant factors in connection with the particular matter in hand, and second, the capacity to focus or 'converge' on one's thinking on whatever factors have been decide upon as relevant. (Freeman, 1968, p.29).

Yet both divergent and convergent thinking are different in character with respect to the problem situations that originally initiated these kinds of activities using the theoretical base put forward by Guilford (1950, 1954). Buttle et.al.(1965), M'Comisky and Freeman (1967) and Freeman et.al. (1968) designed and used the A-C performance task to test or assess the creative design ability in technology subjects, namely, architecture. The power of the A-C performance task is such that it could differentiate between pupils who have received instructions or education in connection with a particular ability (in this case architecture), from those who have not, and hence be measuring the ability in architecture.

It appeared to point to or indicate the relationship between the ability on the A-C performance task and the ability in the four areas of architecture subjects i.e.:

(1) Architectural Design
(2) Architectural Construction
(3) Building Construction
(4) Supplementary: (normally vocational work, embracing the measuring and sketch of existing buildings and model making; the latter, chiefly in the context of architectural design as above.)

Freeman demonstrated, that students with lesser facility on the A-C performance task, will perform poorly on the divergent thinking parts of the test, and poorly on the architectural design. This is due to their incapability to 'range round' flexibility, ie. to diverge, when thinking over a particular problem. However, these same students tend to score higher on convergent thinking parts of the task than on the divergent. This suggests that 'divergent' thinking is closely related to creativity in architectural (technological) design, in terms of intellectual resourcefulness and fluency in origination and developing ideas. However, 'convergent' thinking, i.e. the sort of thinking which we call for when dealing with logical- type problems, which leads, because of our previous education or training, to one right answer only would seemingly have an inhibiting effect. Furthermore, the abilities involved in A-C performance tasks have elements which are common in other technology subjects, such as, electrical/electronics and mechanical engineering.

For instance, in electrical/electronics engineering subjects, the parallels can be seen at two levels. At the first level, there are some similarities between the task-demand of the A-C performance task as a whole and the task-demand involved in the early stages of design technology or engineering education. For example, A-C Performance tasks basically involve a set of blocks, which pupils are required to organise in terms of different concepts e.g. size, shape, solidity, etc. This is similar to what is involved in the early stages of learning about components in electrical/electronics (technology) subjects. In circuitry, for example, where there is a range of components, such as transistor, capacitor, reactor etc., each one has one or more related concepts; e.g. rectification, amplification, in the case of the transistor. The pupils have to learn, as beginners in an engineering (technology) course, to relate the appropriate concept to each component, in terms of its particular function in the circuit as a whole. Thus, it can be said that the same mental processes are involved in both: perceptual discrimination and (clear-headed) differentiation in relating concept (such as rectification, amplification etc.) to tangible things or objects: components, in the case of electrical/electronic circuits; blocks, in the case of the A-C performance task. In both cases the appropriateness of the concept which is related to the particular objects, must be seen in terms of what is involved as a whole.

At the second level the similarity between the ability involved in the A-C performance task and electrical/electronics engineering, has to do with the capacity for originating and developing ideas particularly in design and creativity. This kind of ability is pronounced in the 'divergent' part of the A-C task. In this part of the task it is worth remembering that, the pupils are required to range around in thinking and sample possibilities in their search for the relevant factors in arriving at a solution to the particular sub-test on which they are engaged. In technological designing as in electrical/electronic courses, one would find similar kind of demands perhaps much more complex kinds.

Some mention ought to be made here about the basis of M'Comisky's A-C performance task. As mentioned earlier the basis of A-C performance tasks was Guilford's model (1959) of the structure of intellect, where divergent productive abilities (as seen in technological activity) is one of the range of human abilities.

Guilford's work (1959) is best understood within the frame-work of the general concept of intelligence. The theoretical background of formation, on which he has built his work involves the conception of congeries of primary abilities which are related to each other in multiple second order factors defining wider ranging abilities of greater generality. (Freeman et.al., 1968, p.20).

The incorporative theory of the mind referred to as the 'structure of intellect model', which emerged afterwards is fully discussed in a well known article namely, 'the three faces of intellect' by Guilford (1959). Guilford derives his theory from a whole body of critical work some of which are his, stimulated by the work of Charles Spearman (1904) on speculative conception of general intelligence which needed qualification and elaboration. It is from Spearman's theory that the central problems in studying intelligence and ability namely, the existence of general intelligence; the existence of special as opposed to general traits; the existence or multiple group factors, first came to light. Since then there has been a great deal of expertise to facilitate the analysis of multiple intellectual factors have developed. (Burt, 1927); (Thompson, 1939); (Vernon, 1950); (Thurstone, 1938).

However at the same time parallel consideration was given to the use and development of psychological tests and test batteries, as well as practical education. Of importance was the attractiveness to early educators or the notion of 'g' as a factor of general intelligence, because 'g' factor generated the idea of using a single numerical score as an index of general intelligence.

The development, construction, and use of psychological tests using multiple factor analysis by Spearman, Burt, Vernon, Guilford, etc., as well as the reported low correlation between individual scores on different tests gave rise to the investigation of multiple intelligence factors. This involved a theoretical re-examination and the development of 'g' concept as a general intellectual factor.

It is worth remembering, that with respect to the general theories of multiple intelligence factors two camps namely, theories of Vernon (1950) and Burt (1949) representing the British views and the theories of Thurstone (1935) and Guilford (1959) representing the American views exist, but differ in some important respects. Drawing our attention to this distinction and outlining some important difference(s) clearly Wiseman (1967, p.177) asserts that, the British tend to see the structure of the mind as an hierarchy general ability, 'g' subsumed by many factors each of which may be broken down into similar elements. Thurstone and other American writers on the other hand, conceive of the mind as consisting of a miscellaneous assortment of primary abilities. These however are themselves related to each other and by the technique of 'second-order' factors more pervasive and wide ranging abilities may be postulated. Both views at the end reach the concept or hierarchical structure and the end product of the two opposing schools bear strong resemblance.

No doubt before long, further research will bring the emergence of a rapprochement.

Basing his theory of intelligence on the existence of multiple 'group' factors Guilford assumes that, there are special intellectual abilities which taken collectively may be regarded as forming intelligence. He likened this to a commonwealth rather than a nation.

By using a comprehensive theoretical system or model called the 'structure of intellect model' which incorporates known intellectual factors, Guilford predicts additional abilities not previously shown. These abilities have been classified in three different ways namely:

a) a difference between the visual, forms, numbers and meaningful object involved, is classified as the difference in 'CONTENT';

b) a difference between relations and classes, (and other such mental structures), is classified as a difference in PRODUCT';

c) a difference between processes such as understanding (cognition) and memory, is classified as difference of 'OPERATION'.

After rigorous experimental research and analysis four kinds of CONTENT six kinds of PRODUCT, and five kinds of OPERATION, are revealed. These combine one kind of CONTENT with one kind of PRODUCT and one kind of OPERATION to yield a total of one hundred and twenty unique outcomes each a potential intellectual ability distinct from other abilities.

Guilford and his associates deployed their structure of intellect model, to generate hypotheses regarding unique intellectual abilities. With tests constructed for each in turn they reported approximately seventy (70) intellectual factors. Thus, in brief, Guilford's system had been constructed to

> articulate the range of human abilities including those
> involved in creative endeavour. (Freeman et. al., 1968, p.22)

This suggestion has generated a great deal of research. The reports therefrom point to the fact that

> creativity, effective thinking and the solution of different problems, usually involve the sequential use of convergent and divergent thinking (Freeman et. al., 1968, p.23).

7.9.1 How Technology is taught in Schools

In England and Wales, we can certainly draw on the experiences of the St. William's Foundation project based at the University of Sheffield, Division of Education. Teachers of technology subjects have often adopted the strategy of preventing pupils from thinking about problems. They have always advised pupils to consult them whenever they have difficulties with their work. According to Lords (1987, p.15), the principal reasons for this situation has to do with lack of time and the individual attention which each pupil tends to require.

If technology is defined as a problem-solving process, then the opportunity must be provided for pupils to solve problems.

However, in England and Wales, the picture appear to be slightly different. In the schools visited, with provision of technology in design and technology, science and sometimes, home economics (HE) department etc., it was common to find that teachers of technology subjects adopted much of design and problem-solving approaches in their teaching.

The teachers' experience of design work was brought into their teaching exercise, which allowed them to put technology within the framework of design process. A design brief was always available, which had a design process progressing through problem-analysis, possible solutions, realisation and evaluation, as already mentioned. Some of the design briefs were tightly prescribed, with a narrow outcome, and others were more "open" ended, with diversity of outcome. The class size and the ability of the pupils determined how open a design brief was to be. Project work was also used, although limited to two terms, usually toward the final year. This was more or less to satisfy the requirements of the examining boards.

7.9.2 Atmosphere for Observing Pupils' 'Technological Thinking'

Having accepted the notion of design and problem-solving as being at the heart of technology, it makes sense to look at these processes.

If pupils are working through a technological problem so that as soon as they get into difficulty, they ask the teacher for the answer, then that would not give anyone interested in this area of investigation confidence with respect to the information about the thinking skills used by the pupils. The only useful situation would be one in which the pupils will have to fall back on their own thinking. This is when it is possible to find out how they are trying to tackle the problem.

Given the teaching condition in a typical technology classroom, it is quite difficult to find such a 'useful' situation, because of the difficulty in separating teaching and learning technology.

From my experience of observing problem-solving activity during technology lessons lasting from about one hour, there was perhaps two minutes in which children actually solve problems. Of course these two minutes are very important for an investigation of this nature. If it is assumed that problem solving is at the heart of the process, then technology must be seen as helping the pupils think about solving problems. It was essential to provide the opportunity to solve problems, and to find out how children cope with problem solving when given such, that the tasks described later were designed and administered.

SECTION - 4 ~ DESIGN OF THE EXPERIMENT

CHAPTER 8

DESCRIPTION OF THE DESIGN OF THE EXPERIMENT

8.1 OUTLINE

The purpose of this exploratory study is to investigate the relationship between pupils' technological thinking level and the demands of a technological curriculum. It is apparent from the psychological aspect of the relevant literature review that a Piagetian approach alone is inadequate if we are to get closer to describing the phenomenon of technological thinking, and the activities involved. The use of other protocols, such as those described by Biggs and Collis, Case, Blooms' categories etc., in addition, look promising, and imply that the pupils have to be observed whilst actually engaged in technological problem solving, and thinking about it.

Accordingly, the broad outlines of the experiment are as presented below:

(1) Pupils at the secondary school level in two Inner London Boroughs, Ealing and Wandsworth, were surveyed to determine their levels of technological thinking, using a battery of tests/tasks designed by the investigator.

(2) A taxonomy of the different schemata required for understanding design technology was developed using a Piagetian framework. This was modelled after the taxonomy for science constructed by Shayer and Adey.

(3) The investigator used the developed design technology taxonomy to read and analyse the 1996 new National design technology curriculum activities currently in use, to determine the level of thinking that they appear to demand from the pupils. Furthermore , the investigator used Bloom's taxonomy to redevelop the test items or

written questions for the design & technology curriculum. Practical tasks were also developed . In what follows here, each of these two data collection processes will be considered separately.

(4) Pupils responded to the written and practical tasks.

(5) The investigator analysed all written and practical tasks responses for their cognitive level.

(6) The results were tabulated, compared and interpreted.

The remainder of the chapter explains in details the subjects and population from which they were drawn, description of the instruments and procedure used; there is also a taxonomy of responses, and a taxonomy for analysing design technology used in this investigation.

8.2 THE INSTRUMENT

8.2.1 TEST INSTRUMENTS

Remember that one of the main objectives of this study was to elicit the process skills or "technological thinking", which pupils in secondary schools use when they are solving a technological problem.

To do this, tasks which were thought to test "technological thinking" were to be constructed or assembled and administered. But prior to the construction of these tasks, something about the nature of technology in general and in the classroom in particular was needed.

The review of technology and its meaning for education at the secondary school level served this purpose, and revealed a problem-solving process of design, which required the exercise of intellectual, as well as practical skills. The review did not say something about pupils' process skills or "technological thinking" - at least not directly. It merely gave an idea of the nature of technology in secondary schools, and provided a basis or guide for the construction of "technological thinking" tasks.

It was difficult to say what "technological thinking" was (even operationally), at the secondary school level. But it was thought that a glimpse of it was possible after tasks which presumably tested pupils' "technological thinking", had been constructed, administered, categorised, and analysed. Thus, on the basis of the review on the nature of technology, tasks that were supposed, or whose purpose was, to tell us something about the process skills or thinking in technology, were to be constructed.

8.2.2 GENERAL REQUIREMENTS, DESCRIPTIONS OF AND ASSUMPTIONS REGARDING THE TESTS

The task of designing a "technological thinking" task was the next step, if the above information was to be used in eliciting the process skills which pupils use when they are solving a technological problem.

As a general description, a "technological thinking" task was thought to be the construction of a "device": (e.g. household goods, vehicle for artistic expression, machine, measuring instruments,), or the construction of a process or system: (e.g. timetable, production schedule, ambulance service etc.), which will perform a specified function. An investigation of the natural conditions, (e.g. sociological: census, accident, statistics; scientific: crystal structure, human strength; technological: power in machine tool), or man-made: (causes of accidents, effects on environment or a device or system) was also thought to be a good technological task.

From the general description above, it was obvious that a technological task would be essentially one in which a definite aim or thing has to be achieved or produced. The pupil (or person) engaged in such task, would have to think about the ways and means in which this definite aim was to be achieved. Thus, it made sense to think in terms of design, making, testing, etc., etc. It was assumed that an important component of "technological thinking", would be Piagetian scientific thinking, particularly as both are related on epistemological grounds. This was only part of the story Piaget, after all, did not ask his subjects to design or construct, for example, a pendulum, which would have been a typical technological task.

He instead asked them to find out the underlying principles of operation, given that they had designed or constructed a pendulum. Thus, the two tasks are different, but it was assumed that there would be some similarities. Therefore, in devising technological tasks, particular examples of technological tasks, such as designing, constructing, including a pendulum (science) tasks etc., were considered. On the basis of my observation of how pupils actually proceeded, a set of categories was to be constructed, and served as a basis for assessing pupils' "technological thinking".

In this respect, a simple and typical technological task was designing, constructing or building an artefact or a system etc., or making a system work, as in tracing a fault in a system (a motor vehicle electrical circuit). The assessment of the process as was to be ongoing, observing the pupils at work. By observing a number of pupils doing the same tasks, a set of categories for scoring their production, process, performance, was to emerge. So that the only way forward, was to actually observe pupils doing meaningful technological tasks, (using a video camera where possible), and then construct measures (tests) on the basis of this.

Having got this information empirically, success on this was related to success on Piagetian tasks. It was suspected that the correlation between them would not be significant. However, it was important that the tasks be syllabus related. Six tasks were administered on the assumption they would measure slightly different aspects.

However, intuitively, there was a difference between practical problem-solving of design, and scientific reasoning. Although practical problem-solving required a certain amount of scientific reasoning, perhaps it required something else or may be not. It may be that pupils who are good in science are good in technology: conversely, pupils who are good in technology, can they be good in science?

The tasks to be administered were not complicated. In this respect, teachers of technology subjects were asked what suitable problems to give to their pupils, given that the pupils could understand so much knowledge and principles, and could use certain mechanisms or apparatus. The assumption here was, in effect, that given a certain level of knowledge about the material that a pupil could use, what was a suitable problem to give to him? It is assumed that pupils have knowledge about a particular area or aspect of the tasks which they will do, e.g. electronics. Otherwise, that what would be tested may be their knowledge of electronics, and not the trial process. The same tasks were given to children of different ages, so that something about their levels of thinking could be said. Thinking altered with time, and in order to make a statement which was appropriate to a child, knowledge (or description) of his level of technological thinking was required. By giving tasks that stretch across different ages, such knowledge or (description) was facilitated.

My main interest is related to the psychological processes involved in the application of knowledge.

8.2.3 ADDITIONAL REQUIREMENTS FOR THE TASKS

As pupils with mixed abilities constitute the population in comprehensive schools, tasks were designed which allowed individual pupils to utilise the ability or abilities they had most developed. For example, it was not uncommon to find pupils with reading disability who might well possess normal visual imagery and thought process, doing poorly in a written examination. The tasks were designed to take account of this sort of difficulty by making sure that their possible effect on the pupils' assessment was minimised. This ensured that the task satisfied a wide range of ability.

With this idea in mind, the requirements for some of the tasks included:

(1) administering the task verbally (where necessary) and giving the testee the opportunity or option of reading the questions;

(2) requiring short answers, but providing extra space on the answer sheet for more able students to express themselves;

(3) as far as possible, using simple diagrams liberally to answer questions.

Meeting these requirements could be painstaking and time consuming on the part of the designer.

Thus, the main factor taken into account when designing the tasks was that besides being relevant to the curriculum structure of the school, the task must allow pupils of wide ability range to give responses which they felt were satisfactory. It must be designed such that it measured the mental processes of the pupils in relation to their immediate area of study. Furthermore, these tasks used concepts that (we hope) the pupils have developed during their various practical activities, or principles that have been introduced during the teaching periods.

8.3 GENERAL DESCRIPTION OF THE MEASURING INSTRUMENTS USED DESIGNING & MAKING -

(THE TASKS AND THEIR DESCRIPTION)

Two categories of tasks were administered namely, design and manipulating tasks.

8.3.1 DESIGN TASKS

Tasks D 1.2 to D 1.3, although they have been adapted from STEM (1981), have the main features of design in the National Curriculum used today in schools.

(Note: It should be noted that "design" is intended to include "technological design" where technological concepts are used.)

8.3.1.1 Task D 1.2

Having been satisfied concerning the pupils' understanding of the concept of design by questioning and interviewing, task D 1.2 was designed to make the pupils think about the quality of designs. In general terms, the abilities called for when pupils are engaged in a technological design activity have already been mentioned earlier. The claim is that they include: the ability to perceive a misfit between an artefact (or a system) and a required need; the ability to judge the quality of the misfit (how well does it work) and to express this judgement; the ability to recognise that some things may be done to improve or rectify or change an artefact or if there is a good fit, leave things as they are; the ability to identify relevant criteria needed to improve the quality of fit etc. Let us say that there is a definite aim which we want the pupils to achieve. The pupils are supposedly thinking technologically, when they design something in accordance with a set of aims or objectives. However, there are always many or alternative solutions to a technological problem. So that one has to choose the best possible (or alternative solutions), and give reasons for their choice of solution. It has already been made clear, that the basis of such choice is an adequate understanding of the relevant technological concepts. For these reasons, it is hoped that a glimpse of "technological thinking" used in solving the problem would be apparent

Task D 1.2, is partly designed for this purpose. Regarding design quality as something which is personal, Task D 1.2, shows pictures of some designs which are bad, and some which are not so obvious. Pupils are required to give their reasons for choosing either. This task is also intended to stress the point that, in general, we design things because we want to solve a problem. More specifically, what Task D 1.2 is meant to ascertain includes whether:

a) the pupils can perceive, describe, discuss or otherwise communicate or even identify through investigation, a fit or misfit between an artefact or system and a set of human requirements (needs);

b) they can judge the quality of the fit or misfit, (e.g. how well does it work?) and express this judgement;

c) they can recognise that something may be done to improve, or rectify, or change an artefact, or if there is a good fit, leave things as they are;

d) they can identify relevant criteria needed to improve the quality of fit;

e) they can analyse a misfit (design problem) in ways which take into account such factors as:

i) economic (cost, time, availability of material).

ii) social (awareness of others and of the effects of the designed artefact on them).

iii) ethical (morality of the proposed change).

f) they can combine all the aspects of design problem in a balanced interactive way;

g) they can match ends with means and vice versa;

h) they can look at a particular solution and trace the origin of the problem (as in fault tracing);

i) they can generate a variety of possible solutions to a design problem (a measure of the level of understanding of a particular technological concept.);

j) they can narrow the variety of possible solutions and show commitment to a specific practical proposal;

k) they can explain and justify their reasons for their choice of one in preference of others;

l) they can create a mental picture in their minds of an artefact, system or parts of such items and their description;

m) they can manipulate images (rotate, assemble, change colour or texture or form).

Scoring Criteria

There was no time limit for this task. This task was assessed using adult criteria 1, for correct response, and 0, for incorrect response. Adult criteria were established by giving the task to ten design and technology teachers and using the mean response for each item for scoring the pupils. (See Appendix-1). Furthermore, pupils' responses were classified using SOLO (Structure of Observed Learning Outcome) taxonomy:

0 - for unistructural, functional etc., response; and

1 - for multi-structural, structural etc., response.

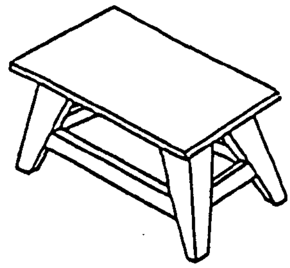
These responses were then assigned appropriate Piagetian levels. e.g.

(2)-for---(2B),

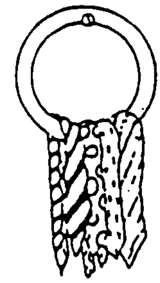
(3)-for---2B/3A.

TASK D 1.2

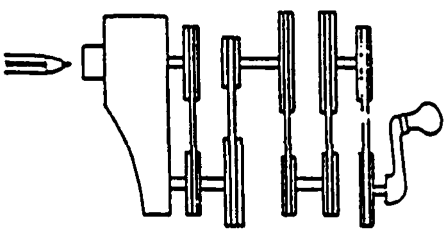
1 *A coffee table*



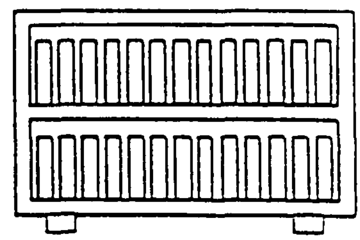
2 *A tie rack*



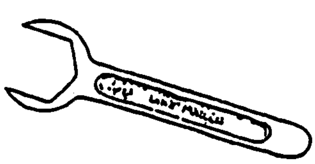
3 *The inside of a pencil sharpener*



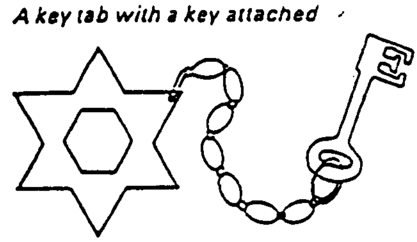
4 *A cassette rack with cassettes*



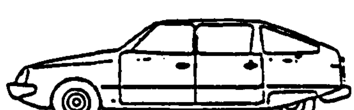
5 *A spanner*



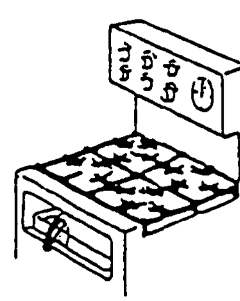
6 *A key tab with a key attached*



7 *A Citroën CX*



8 *Controls on a cooker*



TASK D 1.3 (AERIAL PHOTOGRAPHY)

This design task is intended to make the pupils write down their thought processes and sequence of ideas which occur when they are thinking about their design. This task should tell us whether or not they use the design process as described by Harrison and others. Again, pupils' responses are to be categorised according to the complexity of the responses.

Your school's Geography Department requires an aerial photograph of your school for their map reading course.

Design a device that will carry the camera shown below to a height of at least 25 metres above your school to take a photograph.

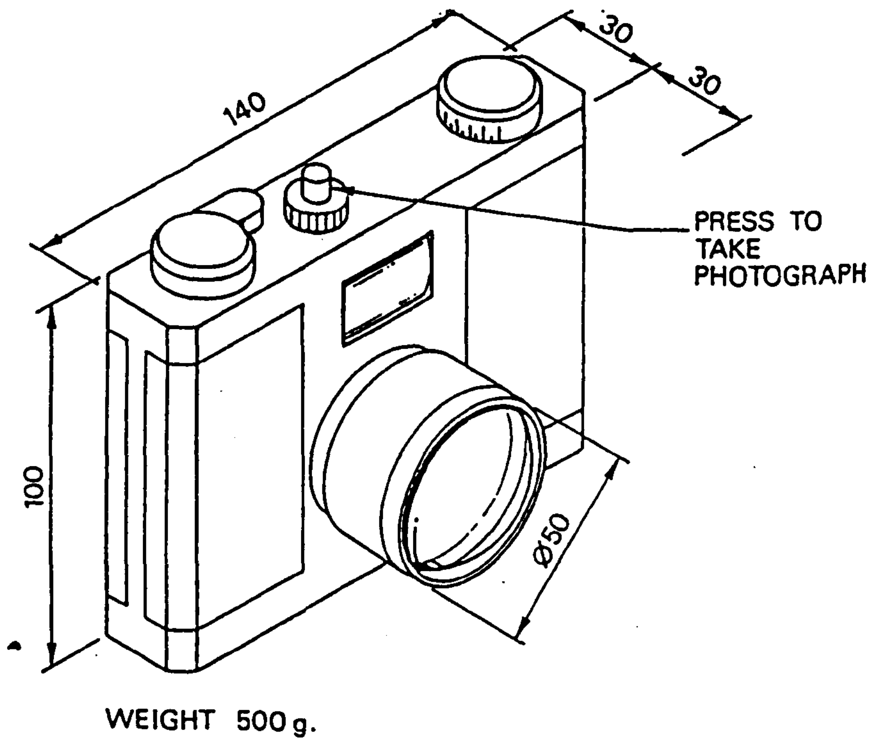
Make a brief note on its construction: then write down your thoughts on the design procedures as they occur.

Scoring Criteria: This task was scored according to how simple, (immediate), unistructural or how complex, multi-structural, pupils, responses were.

0 - for simple etc. responses

1 - for complex responses.

These were further related to Piagetian levels.


140
30
30
PRESS TO TAKE PHOTOGRAPH
100
Ø50
WEIGHT 500 g.

8.4 MANIPULATION TASKS

Manipulation tasks included:

8.4.1(A) SPATIAL ABILITY TASK M-SR 1.1 (Thinking about Shapes)

M-SR 1.1, is concerned with the mental manipulation of shapes and solids, rather than pattern recognition, and tests how well the pupil can think about shapes. There are four sections in this task. The first three sections begin with some examples, to help students to understand what is required of them. They will have to do these first, before they start the real questions, and stop at the end of the section where it says STOP NOW!!!

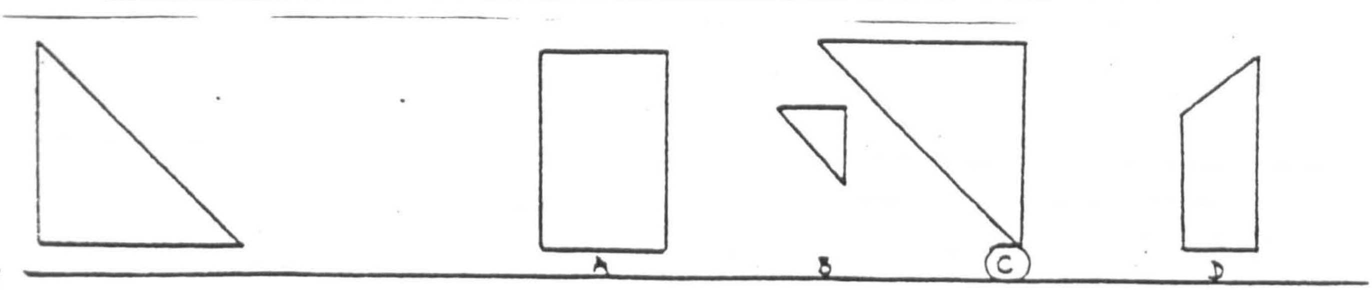
Items 9 - 16, require the pupils mentally to rotate two-dimensional figures: items 17 to 32, require the pupils to visualise the surface of a three dimensional solids. An embedded figure task is also included in the M-SR 1.1 task. (See Appendix - 3 for details).

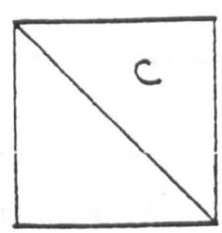
The scoring will be in terms of 1 or 0, i.e. right or wrong.
Below are examples for each section.

SECTION 1

In this section, all the items have 5 shapes. The first shape in each row is a square with a piece missing. From the other 4 shapes in the row, A, B, C or D, choose the one which will fit onto the first to form a square. Circle the letter by the shape you have chosen.

For example



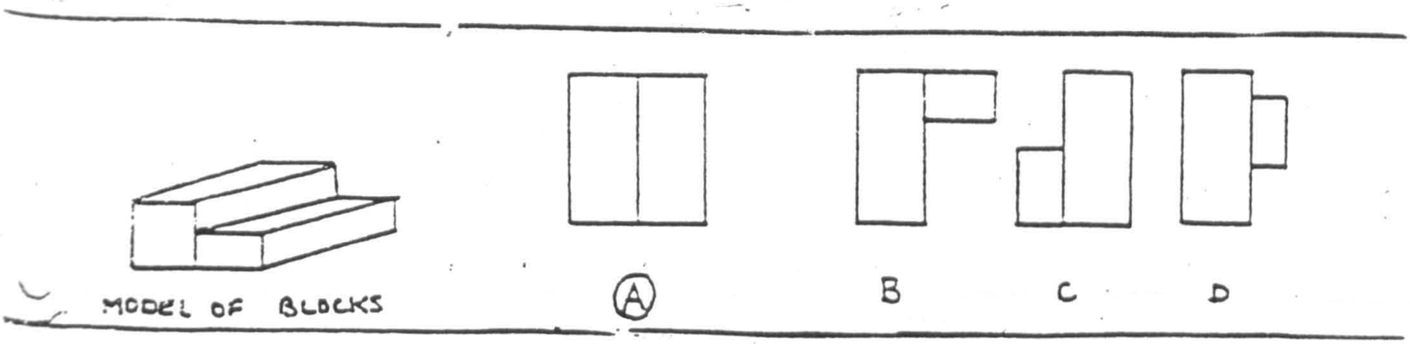


In this example, C is the correct answer. It fits together with the first shape in the row to make a square.

SECTION 2

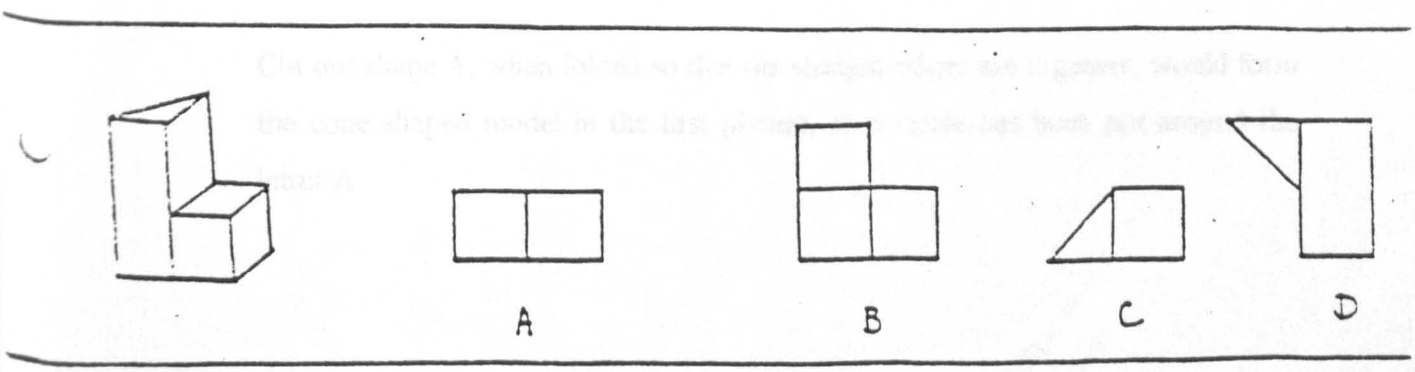
In this section, each question has a picture of a model made with building blocks. This is followed by 4 drawings. One of these drawings shows the shape of the model looking down on it from above. Draw a circle around the letter by the drawing which is correct.

Here is an example



The model is made of two long blocks lying side by side. When it is look at from above, it looks like drawing A. So letter A has been circled.

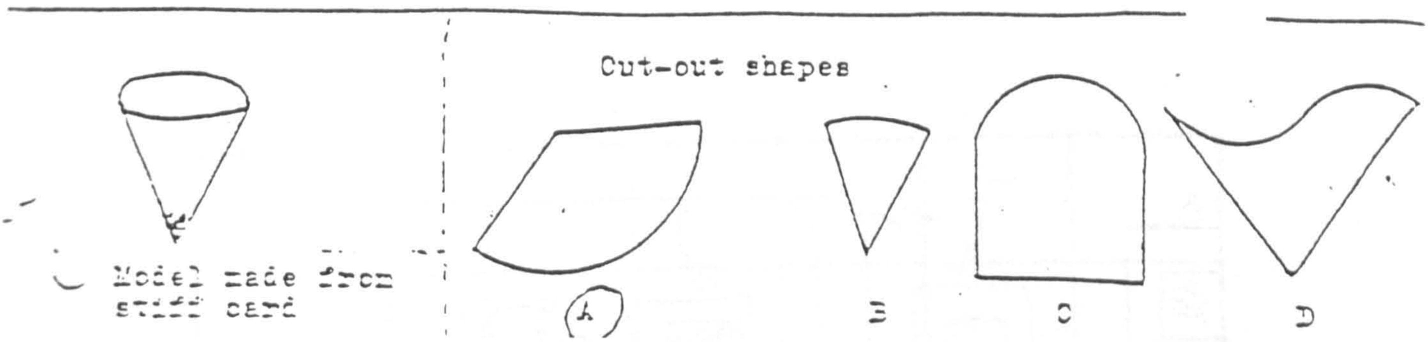
Try the next example yourself.
Your teacher will tell you if your answer is right.
Just put a circle round the letter by the drawing which shows what the model would look like from above.



SECTION 3

In this section each question has a picture of a model made by folding a stiff card cut-out-shape. Besides the picture of the model are 4 drawings of cut out shapes. Choose the shape which when folded would make the model shown in the picture.

Circle the letter under the cut out shape you choose.



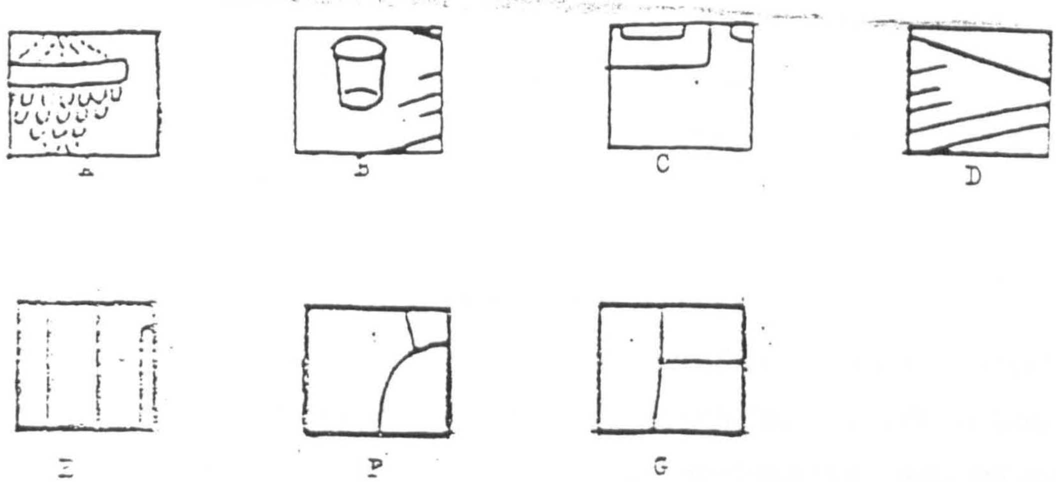
Cut out shape A, when folded so that the straight edges are together, would form the cone shaped model in the first picture, so a circle has been put around the letter A.

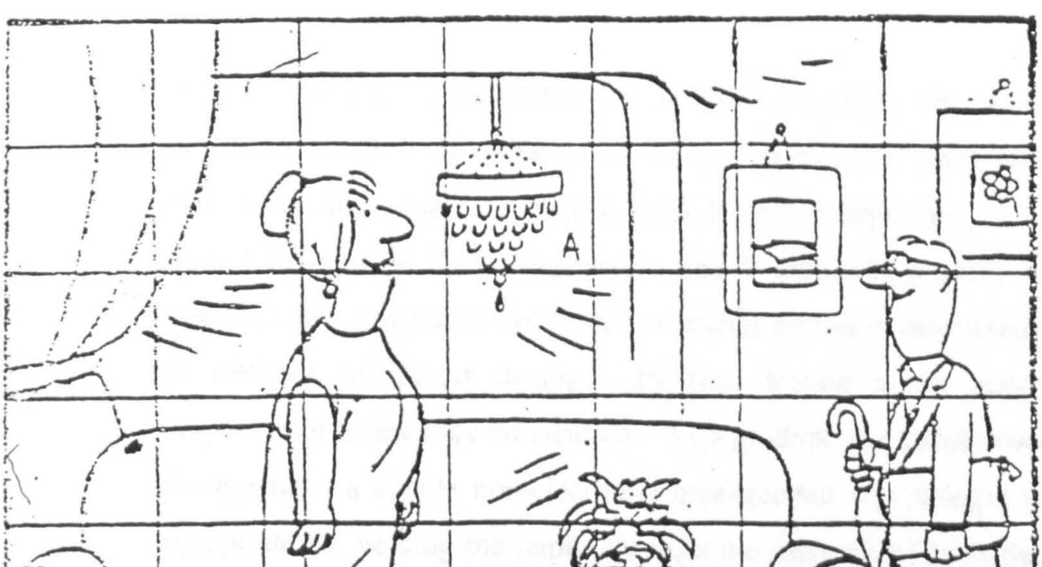
SECTION 4

CAN YOU FIND THE BOXES?

The boxes A, B, C, D, E, F and G are somewhere in this large picture. When you find them put the letter by the box in the square on the big picture.

We've done the first one for you.





8.4.1(B) FAULT TRACING TASK

The aim of this task was partly to simulate fault as may be encountered in a complex electrical/electronic or motor vehicle electrical system. Besides, more importantly, to impute the logic or processes used by the pupils when they are testing circuits or tracing faults etc. This had the advantage of relating the apparatus constructed to the pupils' work situation and providing incentive for them to reach a solution. For this task the pupils need not have received instruction on circuit testing etc.

8.4.1.1 Description

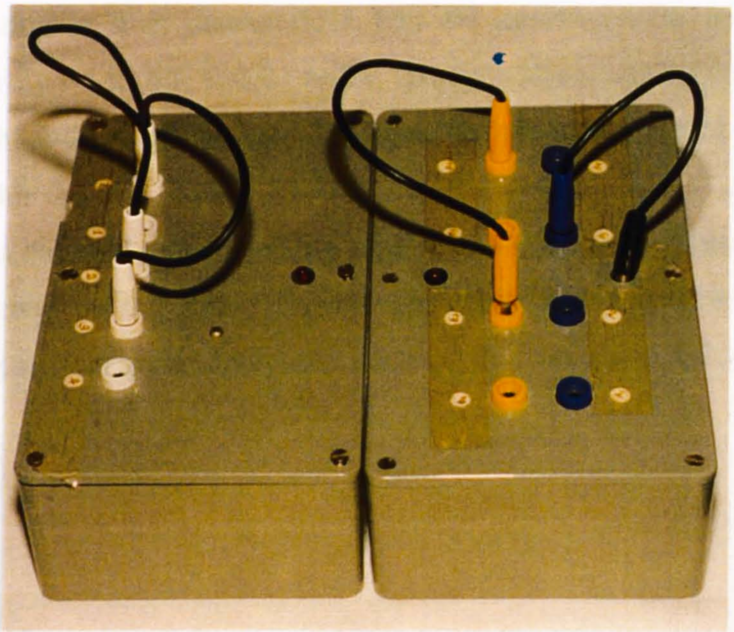
This consists of a sealed box (see overleaf), on which is mounted a series of electric components namely, bulb holder and bulbs, switches, and a number of terminals, which are interconnected inside the box. The pupils are required by the use of a test lamp or voltmeter, to determine the internal connections of the components.

This is in essence a combinatorial problem requiring the pupils to manipulate a series of variables to form a number of combinations. Many technology subjects teachers will readily accept, that it is not unusual to observe that many pupils find it difficult to carry out a systematic test procedure even after receiving intensive instructions on the methods of circuit testing. In fact, testing is an important component of technology curriculum. As a guide to the construction of this apparatus a simple non-electronic arrangement was thought to be appropriate for helping the pupils through the methods of fault finding and circuit testing etc. Thus, in the construction of the apparatus, the electrical components and wiring were very simple. Moreover, the solution to the problem was to be independent of a knowledge of electricity and the pupils needed at most five minutes to reach a solution. In other words, none of the pupils will be given any instruction on circuit testing methods (for the wiring inside the boxes, see the circuit diagrams on the next page.)

FAULT TRACING TASK

SEALED BOXES

Part I



Part II

To what extent is the pupils' ability to manipulate a series of variables related to their formulation and use of a system or combinatorial analysis? This is to be determined by the construction of an identical electrical apparatus whose circuit diagram is shown in fig(1).

The design of this electrical apparatus is such that whilst the pupils are formulating the one-to-one combinations, they must also carry out operations to eliminate a variable. The operations are (1) to form the complete series of one to one combinations using the four sockets B1 to B4, and at the same time (2) manipulate four variables, (i.e. the connections to four sockets A1 to A4) in such a way as to nullify their effect. The construction is such that on to a box are mounted two rows of sockets labelled respectively A1 to A4, and B1 to B4. Directly above and below these two rows, are a pilot light and a single socket. To cause the light to work, two connections have to be made with the two flexible leads provided. That is, from C to A3, and from B2 to B3. It is believed that something about the logical structure used by the pupils would be disclosed by this task. (Note: the pupils would be asked to give reasons for adopting any particular approach to solving this particular task.

8.4.1.2 Designing the Instrument

Two apparatuses were constructed. The first electrical apparatus (Part I) whose internal connection is shown in figure (1) consists of a sealed box on which is mounted five (5) sockets named: Z. 1. 2. 3. 4. and a pilot light. The internal connections are via two relays (or ICs) which are connected in such a way that, to cause the light to work the pupils have to make a number of connections with the flexible leads provided. The connection which completes the circuit for relay (2) causing the bulb to light is Z. I. 3. If a pupil makes the connection Z. I. 3. 4. the relay (2) is energised and the bulb circuit is broken. This can be likened to the bleaching action of the liquid (4) in Piaget's colour liquid experiment. Granted that this first part of the task can be solved using a one-to-one series of combinations, success in this part would suggest that the pupils are able to form some of the series, but not all as it is possible to reach a solution without forming all six combinations required.

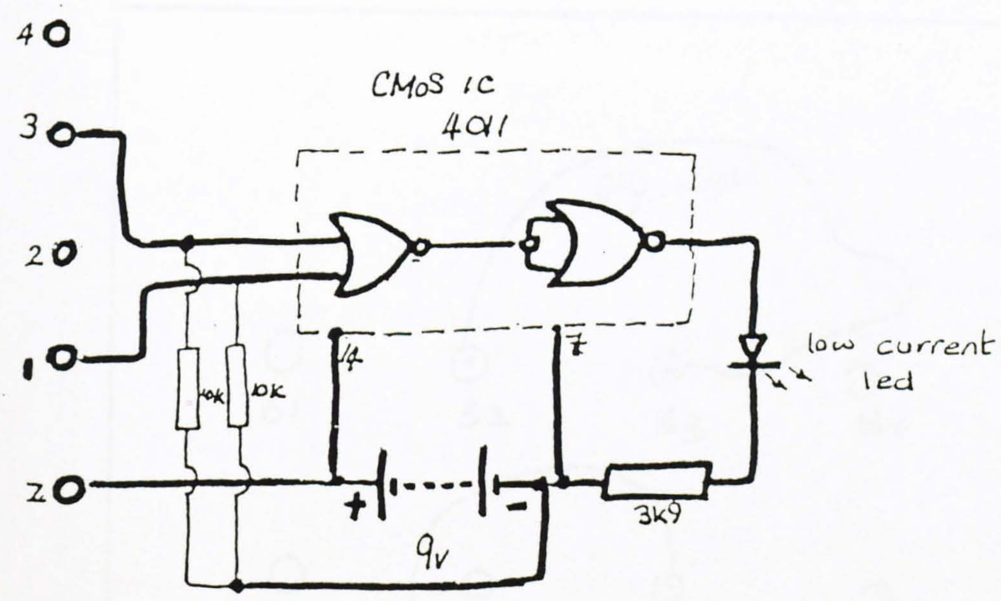
To what extent is the pupils' ability to manipulate a series of variables related to their formulation and use of a system of combinatorial analysis? This is to be determined by the construction of an identical electrical apparatus whose circuit diagram is shown on figure (2a).

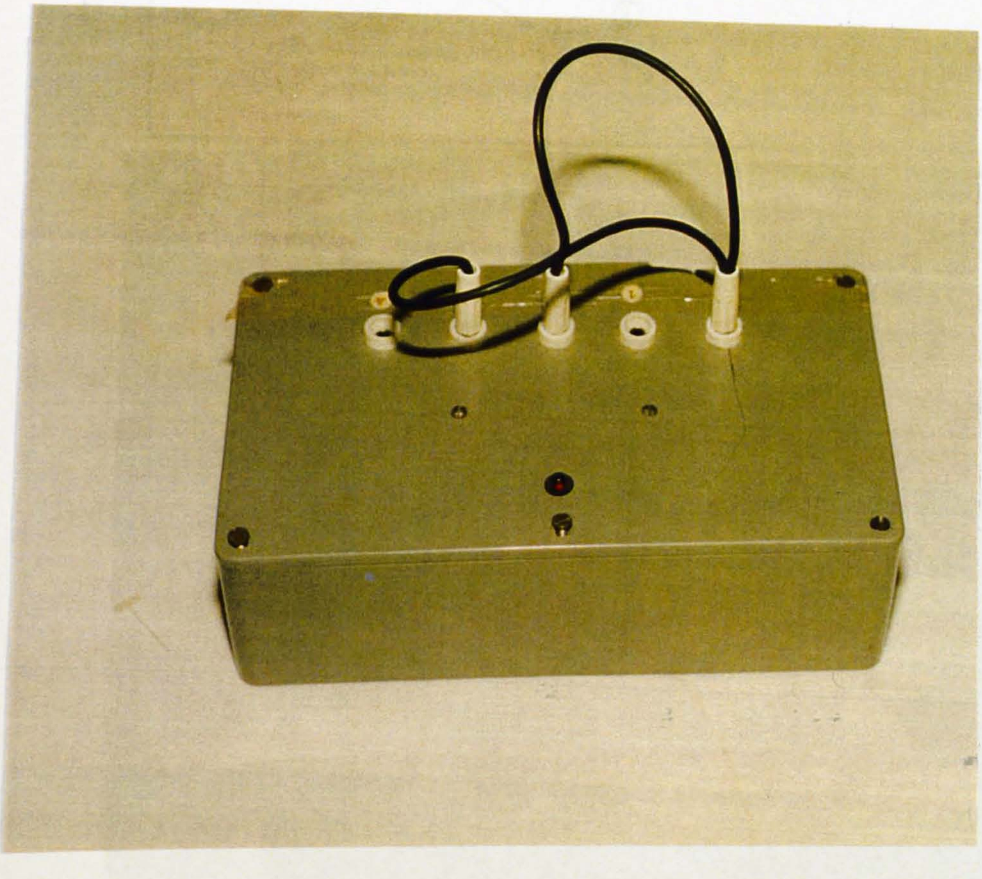
The design of this electrical apparatus is such that whilst the pupils are formulating the one-to-one combinations, they must also carry out operations to eliminate a variable. These operations are (1) to form the complete series of one to one combinations using the four sockets B1 to B4, and at the same time (2) manipulate four variables, (i.e. the connections to four sockets A1 to A4) in such a way as to nullify their effect. The construction is such that on to a box are mounted two rows of sockets labelled respectively A1 to A4, and B1 to B4. Directly above and below these two rows, are a pilot light and a single socket. To cause the light to work, two connections have to be made with the two flexible leads provided. That is, from C to A3, and from B2 to B3. It is believed that something about the logical structure used by the pupils would be disclosed by this task. (Note: the pupils would be asked to give reasons for adopting any particular approach to solving this particular task.

8.4.1.3 Methods Used for Part 1

The pupils will be presented with the apparatus and five flexible leads: each lead being fitted with a single plug at one end, whilst the other end is bare. The pupils will be told that they are required to cause the light to work by using the leads of any number and making any connection. It will first be demonstrated to them that the light in fact works, by using a four pin plug, which can be fitted into the four sockets. The flexible lead from this four pin plug, will be connected into socket Z, which causes the light to work. A second identical plug that will not cause the light to work when connected to the socket Z will be connected to the apparatus, as part of the demonstration to show the pupils that the connection Z is a factor in the solution to the problem. Each plug will be so connected so as to prevent the pupils deducing the actual connections made.

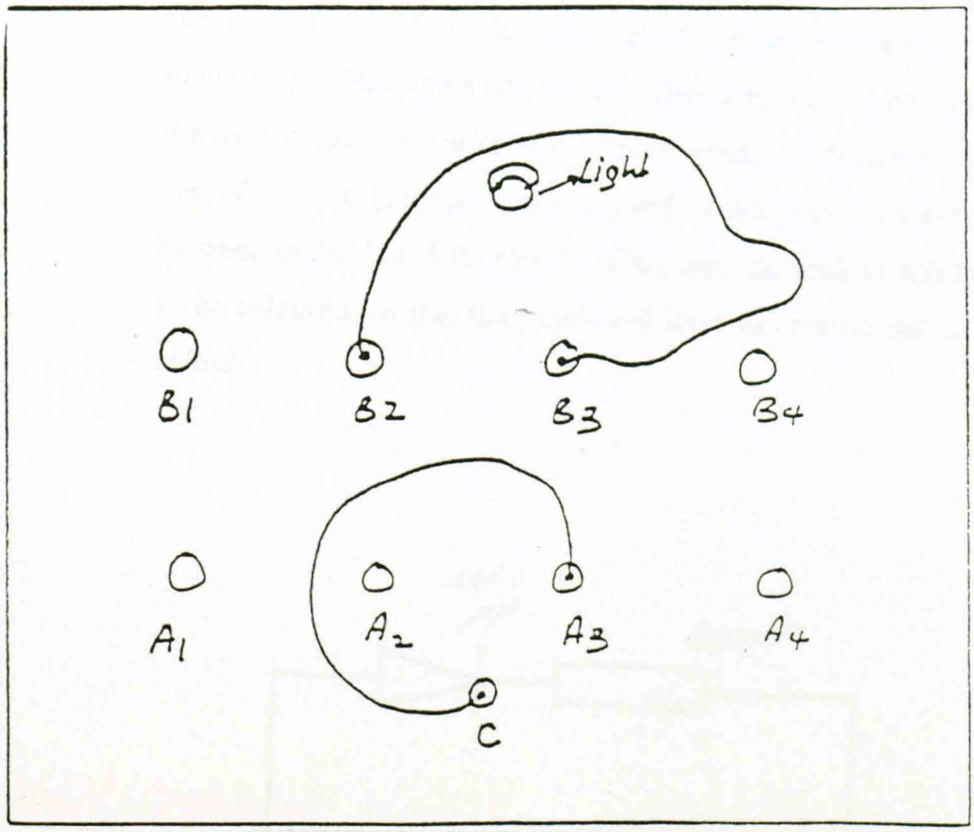
CIRCUIT DIAGRAM Fig. 1

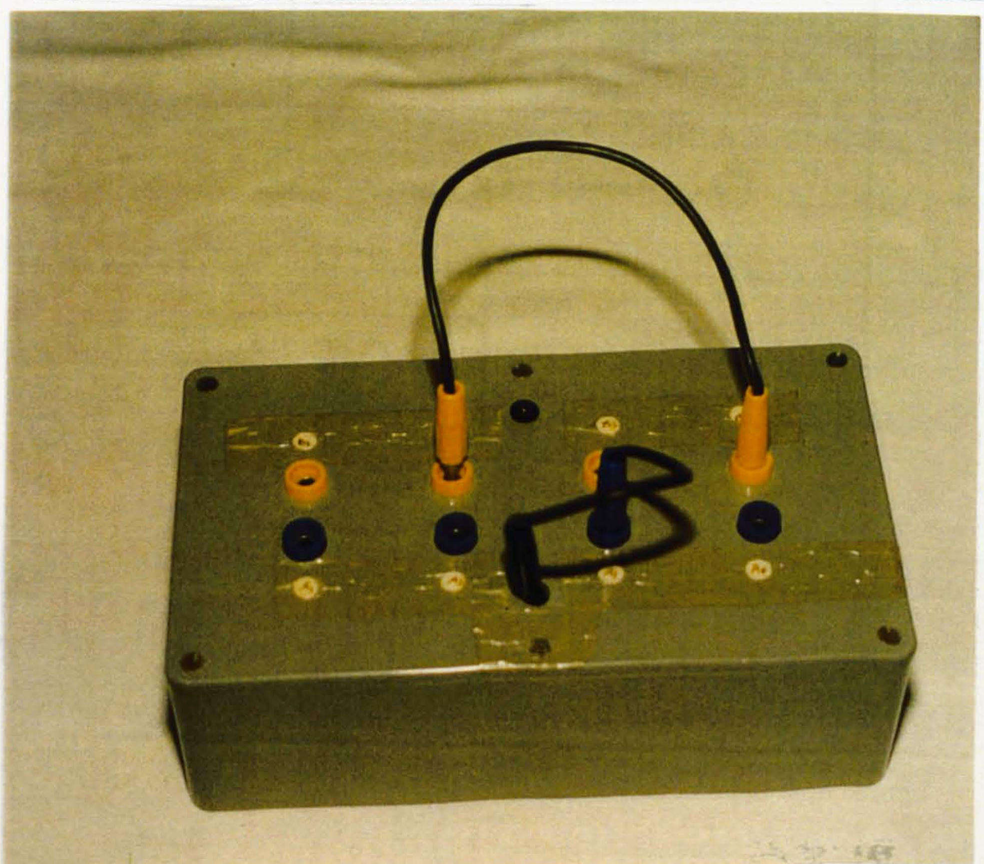




Fault Tracing Task - II

Fig. 2a.





8.4.1.4 Methods Used for Part II

The methods used for Part II will be similar to the one just described above. The pupils will be presented with the apparatus, and two (2) flexible leads, which are fitted at each end with a single plug. The pupils will be told, that they will have to make the right connections with one or both leads. Furthermore, that one of the two (2) leads must be used to make the connections between socket C and the row A. The plugs and sockets will have to be coloured, so that the pupils will have to connect colour to colour.

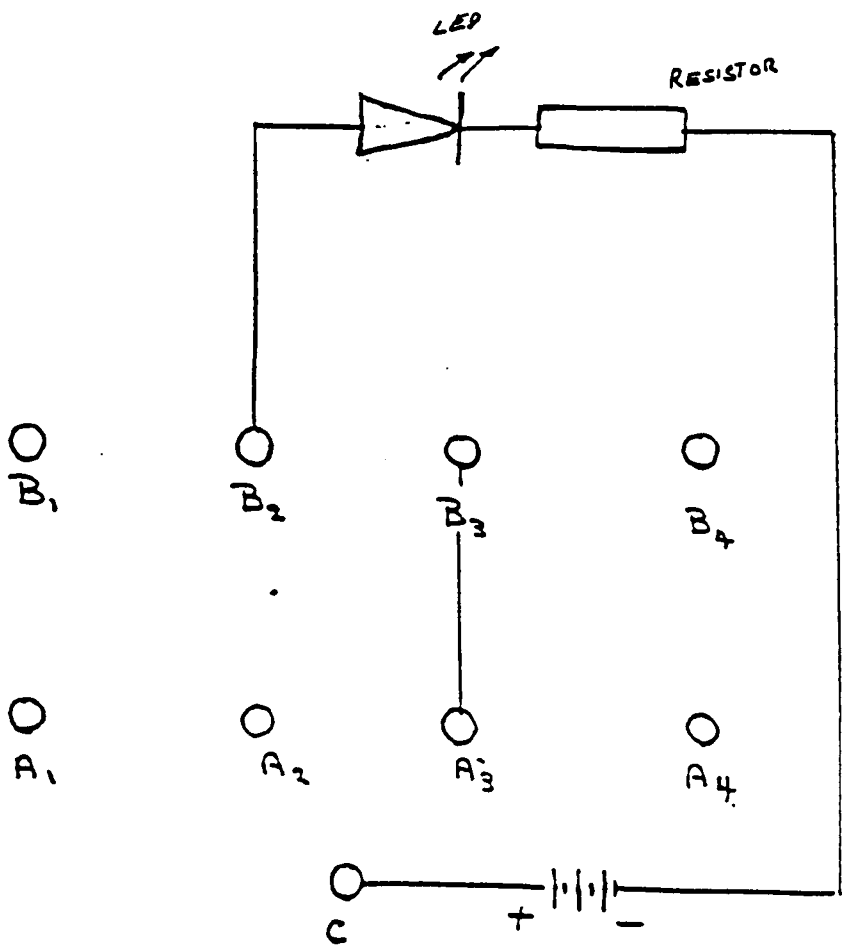


Fig-2a

8.4.1.5 Scoring Procedure/Recording System Used

The pre-prepared sheets which will be used for recording, is as shown for both tasks. With them, it should be possible to record the processes used by the pupils in their attempts to reach a solution. The scoring procedure is as shown below.

The pupils were scored 1, for successful completion of the task and 0, for unsuccessful completion. Time taken to do the task, was also recorded.

Answersheet

Print your name, class, age, and sex.

Name.------------------------ Age.-----years, --------months

Class.----------------------- Sex. ----- male

----- female

A_1	B-B	B-B	B-B	B-B	B-B	B-B	A	B-B	B-B	B-B	B-B	B-B	B-B
A_{1234}	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A_{1234}	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A_{1234}	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A_{1234}	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4
A	1-2	1-3	1-4	2-3	2-4	3-4	A	1-2	1-3	1-4	2-3	2-4	3-4

8.4.1(C) Abstract-Concrete (A-C) Performance Task

However, given Dodd's (1978) summary description of the design process involved in technology, a task was needed which could allow the 'divergent' and 'convergent' thinking abilities to be observed and described. In this respect, M'Comisky's (1961) A-C performance test, which purported to make the same intellectual demands as those in 'core' design technology subjects, namely, design and construction, was adopted. The theoretical underpinning of M'Comisky's task is the broader conception of the nature of intellectual ability put forward by Guilford (1950, 1954) in the USA, and Hudson (1958, 1956) in the UK.

8.4.1.C1 Attraction of A-C Performance Task

It is principally for the reasons outlined in the Contextual Analysis section of the Literature review that the A-C performance task has been adopted in this investigation to emphasise both aspects of thinking. There are two parts to each aspects of thinking, so that the combined score for the four parts gives a measure of the testee's overall ability to think

8.4.1.C2 Description, Administering and Scoring of the Test

The A-C performance task, is made up of sixteen blocks, with ten characteristics which are different. (see fig.-2) Some of the characteristics are related, e.g. size, height, and others are not related, e.g. shape, colour. There are, however, four parts to this task. The first two parts require the pupils to think "divergently". In the first of these, the pupils are required to arrange the sixteen randomly presenting blocks into two groups of eight blocks each, in four different ways: the particular principle on which the individual pupil does this is in each instance chosen by himself. An instance of a two group sorting in terms of size is as shown.

Fig. 2

A-C Performance Task (16 Blocks)

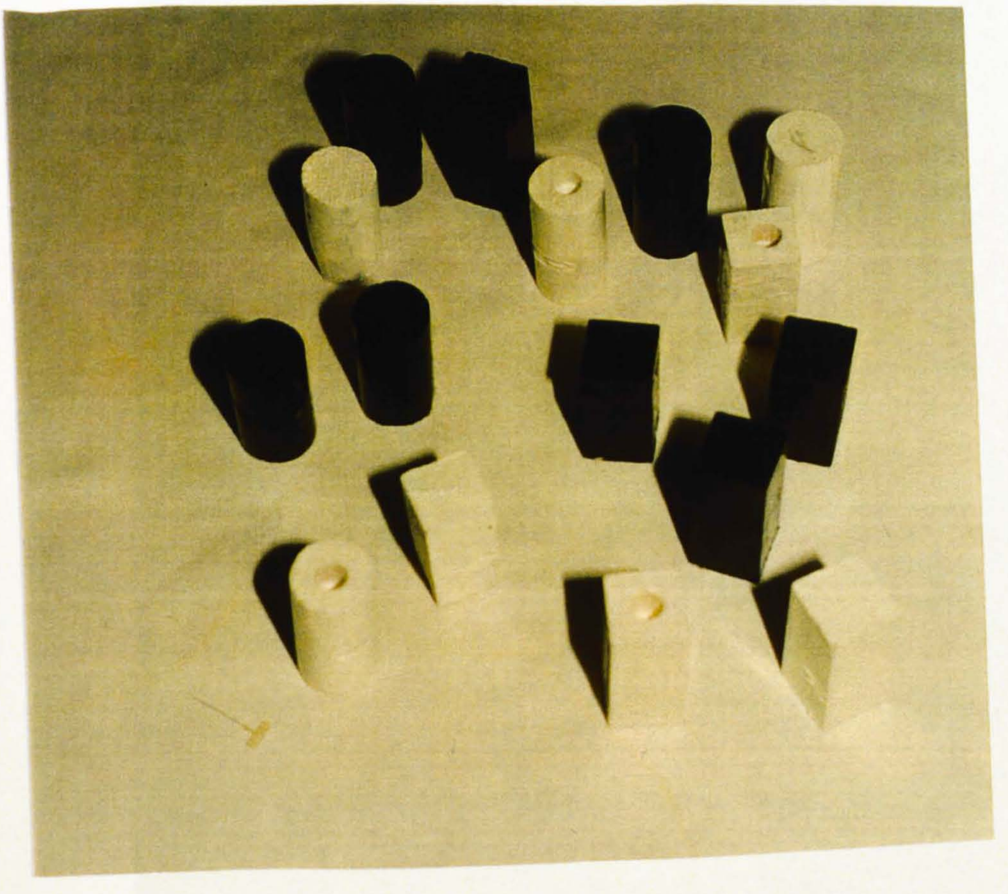


Fig. 3 A-C Performance Task (2-group sorting in terms of size)

To summarise the first task: sixteen randomly presented blocks, to be arranged in two groups of eight blocks each, in four different ways, using any principle. In the second task, the pupils are required to sort the blocks into four groups of four blocks each, in three different ways. This second divergent thinking series is the most difficult part of the test.

In the remaining part of the test, the pupils are required to think "convergently". In the first section, the pupils are required to again arrange the blocks into two groups of eight blocks each, but in the six different ways which they are required to do this, they are told what principle to use. In the second section, the pupils are required to arrange the blocks in four groups of four blocks each, in nine different ways; once again, they are told which principle to use (see figure-4)

In these last two parts of the task, the pupils are required to focus, ie. "converge", their thinking on a particular sorting principle that they have been told to use, and to exclude the consideration of the irrelevant characteristics of the blocks while doing this. The demands or requirements on the part of the pupils are different in this part of the test, from the first part, where the pupils were required to "diverge" their thinking while deciding what particular principle to use for the sorting. When these two sets of scores (for "convergent" and "divergent" thinking parts of the task) are taken together, they give some indication of the 'balance' in the pupils' thought processes. All pupils' ability to carry out the required sorting; and for time taken in carrying out the sorting. Total accuracy score is obtained by combining the accuracy scores for the four parts of for the four parts of the test. Also the total time taken is obtained by combining the accuracy scores for the four parts of the task.

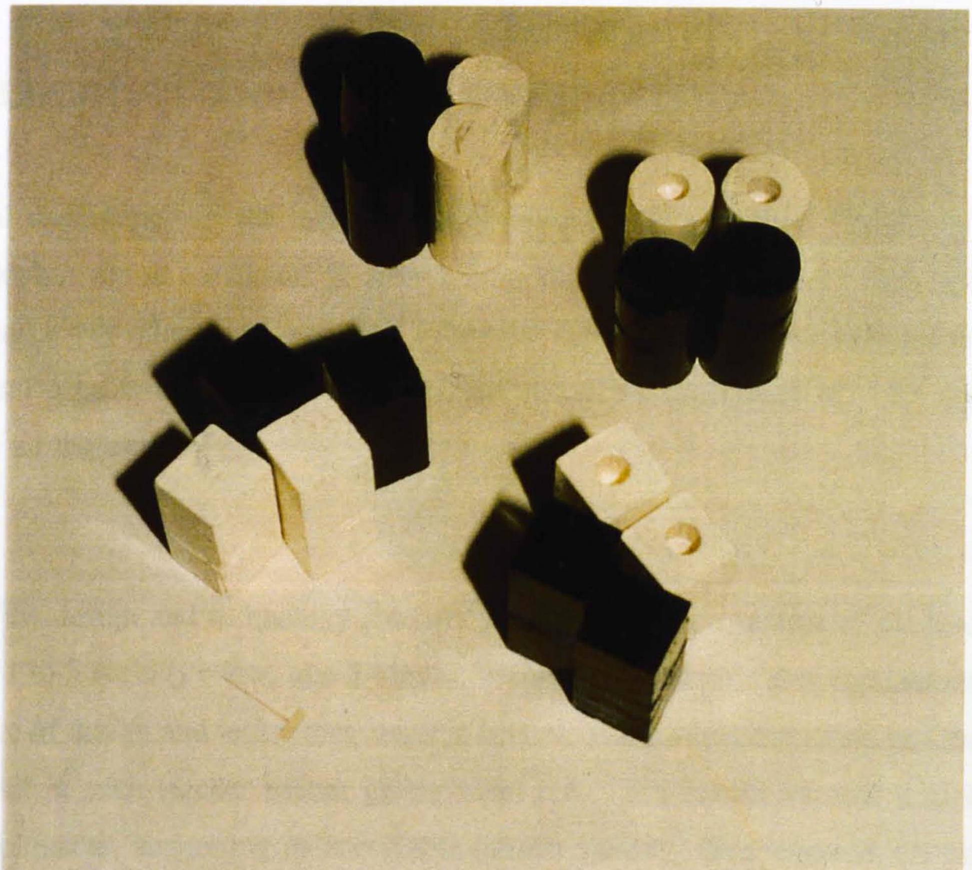


Fig 4 **<u>A four-group sorting in terms of SHAPE SIZE</u>**

8.5 OTHER TESTS ADMINISTERED

8.5.1 SCIENCE THINKING TEST

One Piagetian task (Pendulum task) was administered and scored in accordance with the procedure outlined by Kuchemann (1979) (see appendix-4). In this science thinking task, pupils' ability to sort out the effects of three variables, namely, length, weight, and push of a pendulum, is investigated. It is imagined that this "sorting" ability will be similar to those in A-C performance task. This test was to give some indication of pupils' current thinking level.

8.6 RELIABILITY AND VALIDITY ESTIMATES -

Reliability:

The internal consistency of the tests was determined using a measure (Cronbach's coefficient alpha) whose coefficient is derived from the correlation between each item in the test and every other item in the test. (See the appendix-8) for the estimates for the individual aspects of the test.) An average reliability coefficient of 0.89 was reported for all the tests.

Validity:

Content: Nine design and technology teachers were each given a sample of the tests to rate on a 1 to 5 scale (1=low, and 5=high), according to whether they represented the main core of design and technology work in school. The investigator explained the tasks in detail to each teacher before giving them out. The results showed a high degree of agreement, suggesting an acceptable content validity. (See appendix (7) for details of the teachers' rating of the tests)

Concurrent Validity estimate was obtained. Scores obtained from the tests were correlated with the pupil's technology examinations scores. A correlation of 0.8 was obtained.

8.7 SAMPLE (General Remarks)

To make valid statements about pupils' technological thinking levels/skills in secondary schools, ideally, the sample should include properly weighted representatives of:

(1) all the schools in the locality/region where there is design and technology department.

(2) boys and girls;

(3) rural and urban schools;

(4) five age groups;

(5) three to five socio-economic groups;

In this investigation, as in all empirical studies, the factors which were actually investigated, were limited by time and money. Three schools across two Inner London Boroughs graded, according to their academic success/standards etc., by teachers as "bad", "moderate", and "good", were chosen.

However, the real guiding factor in deciding which variables to consider, was the overall aim of the investigation, which was to provide teachers and others concerned with technology curriculum data which will be useful. For instance, how are pupils in years 7 to 11 likely to think when solving technology problems.

The sampling strategy used here involved picking out the chosen schools and testing as many samples of pupils representative of the year groups.

The results from this sort of survey ensured that reliable statements about pupils in the schools tested were made. This was, however, of limited value. Nevertheless, given the description of the schools chosen, it was possible to also make some extrapolation to other schools which were similarly placed. No attempt was made to investigate or control for the variation in social economic status of the pupils.

8.8 SUBJECTS

The subjects who participated in this exercise, were chosen from 3 schools, namely, Villier's High, Featherstone High and Battersea Technology, across two Inner London Boroughs of Ealing and Wandsworth. With the total support and co-operation of the schools Departmental Heads, the experimental work went smoothly.

As a general remark, the schools selected fell within slightly below and above the National average in pupils, performance. The schools were located in areas of Inner and Outer London where the ethnic mix was balanced, slightly tipped towards the ethnic minority population ie. Asian, (Villiers & Featherstone High), and Afro-Caribbean, (Battersea Technology College).

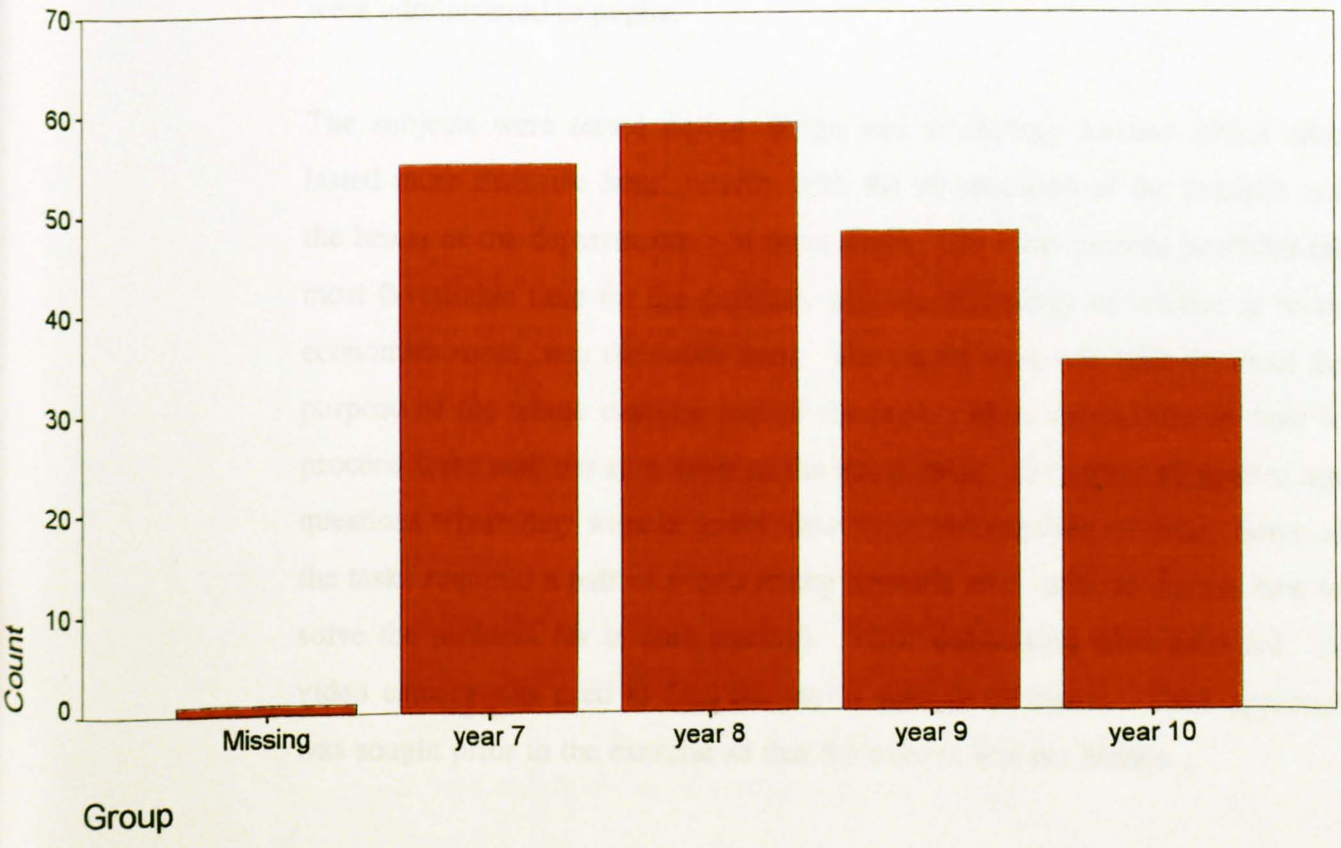
Each of the selected school's design and technology department was reasonably equipped to ensure that all the pupils access the National Curriculum which all the three schools teach. The teachers in all three schools were dedicated, experienced and well qualified in the subject. The investigator was familiar with the design and technology department of the three schools, having been a member of the staff. The schools were mixed gender comprehensive schools, and pupils were of KS 3 & 4 levels (age range between 11 and 16yrs).

The schools' design and technology departments adopted a curriculum approach that introduced the pupils to the knowledge and skills that might be required for a long project through several preparatory short "skills modules." Broad project themes that tended to unite the subject specialism within the department, were often identified at the Faculty planning meetings. Whereas, the faculty in one school consisted of science, technology and art, in another, it consisted of art, home economics and technology. Projects were often identified by each teacher to relate to a theme and to involve the pupils in using the skills developed in the skills modules from each curriculum area.

It must be emphasised that, no attempt was made to compare the performance of each year group either between or within these schools. Instead, the thinking typically used by pupils of each year group was described and analysed. Teaching strategy included giving sometimes a short lesson on a particular topic, issuing information sheets relating to the topic and prescribing a task to do either individually or in pairs.

In total one hundred and ninety seven pupils (95 boys and 102 girls) from the three schools were randomly selected to participate in the research work. The subjects were distributed amongst the year groups and Key Stages as follows:

KS	Year	Boys	Girls	Total	Grand Total
3	7	30	25	55	
3	8	25	35	60	
3	9	28	20	48	
4	10	12	22	34	197



DISTRIBUTION OF SAMPLE TESTED AMONGST THE YEAR GROUPS

8.9 PROCEDURE

8.9.1(A) <u>Pilot Study</u>

A fuller report of this pilot study has been published in the International Journal of Technology and Design Education,(1992, 2,2, pp.54-64)

The pilot study was undertaken by the investigator with 50 pupils in secondary school in Sheffield in order to determine whether the planned procedures were possible.

The investigator read and analysed the Curriculum on design and technology, pupil's work, as well as developed and discussed with teachers tasks which were administered to pupils.

The subjects were tested during design and technology lessons which often lasted more than one hour, usually with the co-operation of the teachers and the heads of the departments. At other times, free class periods provided the most favourable time for the exercise, and the technology or science or home economics room, was the venue used. The pupils were told initially about the purpose of the whole exercise and of the tests. Then instructions on how to proceed were read out as written on the test papers. They were allowed to ask questions where they were in doubt about what was required of them. Some of the tasks required a pair of pupils sitting opposite each other to discuss how to solve the problem (as in fault tracing). Their discussions were recorded. A video camera was used to film the pupils solving problems. Their approval was sought prior to the exercise so that the camera was not hidden.

For some of the tasks, there was no time limit for completion, except for the A-C performance task. This was to allow sufficient time for thinking.

8.9.1(B) <u>Analysis Done</u>

Mindful of the overall aim of this investigation and the notion behind designing many tests for pupils of different ages etc., a lot of questions began to surface. These questions stem from those posed at the beginning of chapter-1. Attempts at answering them provided a guide to the kind of analyses best suited for the data collected.

It was also interesting to know whether or not these tests related to anything else other than themselves. Furthermore, looking at the categories of the tests, it was asked, what was the relationship between the pupils' capacity to see a good design and their capacity to manipulate objects? Last, but not the least, with regard to technological thinking, was what was so termed, largely accounted for in terms of Piaget's formal operation? These and other exploratory questions lent themselves to three types of analyses, namely, psychometric, simple developmental and qualitative.

Whereas psychometric analysis told us something about the structure of technological thinking, the question of what happened with increasing ages of the pupils required a simple developmental analysis. It was hoped that differential levels of operativity would emerge from the latter analysis. Qualitative analysis would be done on the test results.

8.9.1(C) <u>Statistics Used</u>

Some correlation (Pearson's Product-Moment) and factor analyses were done. Irrespective of the limitations of factor analysis, it provided a useful description of what was involved in pupils' performance. Chi-Square and Analysis of Variance were also used.

8.9.2 DESIGN AND TECHNOLOGY CURRICULUM ANALYSED

The other aspect of the experiment described here was about looking closely at the technology curriculum used in secondary schools, and for each activity therein, to try and assess the demand it made on pupils' thinking, i.e. the abilities needed to achieve success in it

The categorisation of teaching and learning activities in technology was uncommon, perhaps because the curriculum was not published in such detail as to allow one to tell from the printed page what sort of activities were supposed to be going on in the class room. It would be practically impossible to analyse the bits of knowledge which comprised an examination syllabus into cognitive demand levels, where the syllabus did not give indication of the actual teaching/learning procedures to be employed.

Even in other well-researched curriculum areas such as Nuffield science schemes, with its detailed guides, one hesitated to give levels to the activities since what actually occurred in the schools' laboratory were nothing more than individual teachers' idiosyncratic interpretations of the printed version.

The most that could be done was to postulate the demand level of an activity, on the assumption that it would be taught exactly as written. The mediating role of the teacher between the written curriculum and class room activity was a problematic one both for the curriculum worker and anyone attempting to analyse the curriculum.
In view of this problem, samples of pupils' own work on certain aspects of the curriculum activity were also used to provide vital clues to the demand made on them by the curriculum. Besides, the objectives of each of the different aspects of the New National curriculum on design and technology were read thoroughly and subsequently categorised in accordance with Bloom's taxonomy. These categories were then related to Piagetian protocol, and assigned the appropriate characteristics as shown overleaf:

Bloom's Categories	Piagetian Categories	Levels
	Pre-operational	1
Knowledge	Early Concrete	2
Comprehension	Early Concrete	2
Analysis	Late Concrete	3
Application	Early Formal	4
Synthesis	Late Formal	5
Evaluation	Late Formal	5

8.9.3 DESIGN AND TECHNOLOGY TAXONOMY (DEVELOPMENT)

Design and technology taxonomy was another instrument developed and used during this investigation for estimating the level of thinking in Piaget's terms, demanded by design and technology education. This taxonomy was designed using Piagetian framework and Shayer and Adey (1981) taxonomy in science education. Apart from the fact that the literature review section points to the need for a taxonomy in design and technology (Siraj-Blatchford, 1993), (Roden, 1997), it is in acquiring a deeper understanding of the ways pupils think in design and technology in order to facilitate a development of a good design and technology curriculum that motivated the present development.

The development of this taxonomy for design and technology required an understanding of and reflection on the work of Piaget in science due to its strong relationship with design and technology as demonstrated in the literature review section as well as other areas of the curriculum that was reviewed in the previous section. Its application requires reading through and analyzing the objectives in the New National Curriculum on design and technology KS 3&4, and a very delicate deployment of Bloom's and Solo's taxonomies, plus pupils responses to design and technology tasks given.

In the contextual analysis section of the literature review, some of these process skills were identified as combinatorial reasoning, classification, seriation ability, proportional reasoning, causality, frame of reference. Some general remarks about each of these were made. Here, a detailed description of each process area and their levels will be done. How it has been (or can be) used in design and technology work has been demonstrated and explained in the results and analyses section.

8.9.3.1 **CLASSIFICATION**

At **Preoperational** level the pupils will begin or be able to:

- represent an object or recreate one with a mental image. (a child creates a similar object as the one described in a reference book or seen physically.
- draw pictures to represent an object. (circles, squares, and triangles)
- see the association between objects (two things that go together, cup and saucer)
- recognize objects/artifacts/places etc. because of specific characteristics (plane by shape and name)
- recognise qualities (colour, texture)

At **Early Concrete** level pupils will begin or be able to:

- group objects and pictures according to their similarities (cups, tables, chairs)
- describe a quality, attribute, or characteristics of a place or thing in the environment /context.
- describe how characters/components are similar or different.
- describe part of an object/artifact
- recognise more elaborate words in the text (associates oscillation with pendulum)

At **Late Concrete** level pupils will begin or be able to:

- coordinate two attributes of objects and to group the objects according to that coordination.
- state the multi-dimensional characteristics or attributes of a place, thing, or concept in topic.
- synchronize the characteristics of an object in a topic to the events which they share in common.
- classify by multiple criteria
- analyze part-whole relationships of components in a system.
- state the main idea of a project/subject/topic.

At **Early Formal** level pupils will begin or be able to:

- reclassify characteristics of objects in different ways.
- form classification systems not given by the teacher, when necessary.

At **Late Formal** pupils will begin or be able to

- hypothetically elaborate on any of the details of a project/object (hypothesizes the various purposes and qualities of a system)
- comprehend the essence of underlying associations.

make hypothetical arrangements with hypothetical objects.

8.9.3.2 SERIATION

At **Preoperational** level pupils will begin or be able to

- attempt to order objects/components/events of a project but parts are often misplaced (planning scheme)
- develop an awareness of dimensions (tall/short, big/small) and placement (front/back, in/out)
- perceive objects/components/events in a system/project as separate, distinct and unrelated.
- have difficulty understanding and remembering rules (recipe for pizza)

At **Early Concrete** level pupils will begin or be able to:

- list the objects/components of simple project
- state simple functions of main tools/component
- order properties along one relevant dimension (planning)
- understand time sequence/schedule (keeping to time scale)

At **Late Concrete** level pupils will begin or be able to:

- order a set of objects/events along a variety of relevant dimensions, if required.
- question the order of procedure/events if there is inconsistency
- lists the procedure/events/objects/components of a complex activity in chronological order.
- understand and recall rules/principles that are explicitly stated.

At **Early Formal** level pupils will begin or be able to:

- synthesize the series of action/events which formulate the theme of the project/work.
- relate components' functions as series of attempt to reach a solution and thus produce and outcome of the explicit ordering of actions.
- begin to understand (how the) actions of one components/character interact(ing) sequentially with actions of other components/characters
- explain flashback and foreshadowing.

At **Late Formal** pupils will begin or be able to:

- produce an account of the implicit order of activities/events
- draw conclusions about hypothetical relationships in a system.
- hypothesize about actions that are possible beyond what is given.

understand an infinite series of actions/events (input - output process).

8.9.3.3 **SPATIAL TEMPORAL RELATIONSHIPS**

At **Preoperational** level pupils will begin or be able to:

- relate to all spatial situations in project with self as the center.
- respond to action by what is known rather than perceived
- not to deal with speed, time and distance
- acknowledge spatial relationships (functional characters need to be constant)
- be aware of temporal relationship.
- judge spatial order by final position in time and space (smaller/lighter is faster)

At **Early Concrete** level pupils will begin or be able to:

- understand technological concepts (e.g. elevation, organisation)
- respond to activity tied to the person
- identify directionality and position. (left/right, up/down)
- conceptualize time dominated by space (design to suit changing times)
- manipulate technological concepts

At **Late Concrete** level pupils will begin or be able to:

- not consider all spatial/temporal relationships simultaneously.
- describe an event/activity spatially when asked to interpret.

At **Early Formal** level pupil will begin or be able to:

- interpret technological concepts in tasks to themselves.
- understand relationship in an activity when more than one independent relevant variable is involved such as space, time
- interpret activity/events in terms of their spatial/temporal relationship
- consider spatial/temporal relationships simultaneously.

At **Late Formal** level pupils will begin or be able to:

- explain abstract spatial relationships.
- organize implicit temporal relationship.
- appreciate and critiques the variety that spatial/temporal descriptions brings to an events/activity.

8.9.3.4 **CAUSALITY**

At **Preoperational** level pupils will begin or be able to:

- state that actions in activity lead to one another (magically)
- see actions of activity as separate occurrence.
- state that every effect has a cause, but it may not be related to the facts.
- Believe that all moving objects have life (cars)
- Accept details when action consequences are related to rules.
- state conclusions unrelated to the evidence or details.
- enjoy repetition of action
- lump entire sequence of events together.

At **Early Concrete** level pupils will begin or be able to:

- describe simple representations.
- explain that somehow action one led to action two and action two led to action three.
- defend right actions as those which satisfy self needs
- have difficulty with actions in a task beyond direct experience.
- difficulty with conclusions that do not fit directly with stated/set task
- explain one factor causes of action/events.

At **Late Concrete** level pupils will being or be able to:

- construct the causes of an explicit action.
- predict direct consequences.
- impose structure on reality.
- identify teacher's explicit purpose.
- accept consequences when based on details.

At **Early formal** level pupils will begin or be able to:

- construct and link the causes of an action that are implicitly stated.
- interpret physical causes for given action.
- appraise the value of components and their relationship to action/system/events.
- identify teacher's implicit purpose
- identify inconsistencies and gaps in causal connections.

At **Late Formal** level pupils will begin or be able to:

- use models to comprehend a complex action/event.
- explain distortions of causal connections using alternative models.
- evaluate the context to determine the causes of action/events.
- construct conclusions based upon understandings of a variety of implicit and explicit actions/events.
- interpret how solutions occurs.
- formulate predictions based upon future actions/events.
- consider multiple causes for actions/events and that actions/events have multiple effects.

8.9.3.5 <u>FRAME OF REFERENCE</u>

(IMAGING / SPECULATING) - CLUES

At **<u>Preoperational</u>** level pupils will begin or be able to:

- state activity/events in terms of his/her own self (egocentricity.-- I have made a puppet.)
- require pictures or an auditory stimuli to establish the state of an action/event in a project/activity.
- not to take the perspective of another in an action.

At **<u>Early Concrete</u>** level pupils will begin or be able to:

- describe actions/events colourfully.
- experience new perceptions and can modify the meaning of a concrete.
- expect the action to be resolved realistically.
- break down structure of object/project

At **<u>Late Concrete</u>** level pupils will begin or be able to:

- recognise that technical word may have different meanings.
- recognise that there differing but alternative solution, and not necessarily able to resolve or co-ordinate the conflict created by these.
- break down the structure of an object/ project.
- defend actions that are comfortable and familiar.

At **<u>Early Formal</u>** level pupils will begin or be able to:

- compare real world with world presented.
- given an appropriate model, recognise that there can be differing parts/view and can co-ordinate these .
- relate to other worlds established (visualise, imaging).
- focus on an object, person, or region.

At **<u>Late Formal</u>** level pupils will begin or be able to:

- produce and discuss alternative models that have different points of view.
- describe other's perspective and can co-ordinate it with own. (Evaluation)
- interpret and accepts alternate accounts of a situation.
- relate to the performance/ functions of components.
- produce an explanatory model of the teacher's idea/view.

8.9.3.6 CORRELATIONAL REASONING

(functional relationships-- in elevations, components, structure ratio load-stress)

At **Preoperational** level pupils will begin or be able to:

- conclusion about changes in design or system are unrelated to the evidence presented.

At **Early Concrete** level pupils will begin or be able to:

- relate design or system to owns experience (modelling)
- overlook information that is related to the conclusion about design or system.
- Intuitively explain relationships within system or design.

At **Late Concrete** level pupils will begin or be able to:

- understand compatible combinations of components/events in a system/design
- perceive changes as design/action occurs.

At **Early Formal** level pupils will begin or be able to:

- explain reciprocal actions/events in a system.
- see positive and negative relations as having equal value in a design/action
- make predictions about out comes when all the details are not stated.
- determine the nature of a relationship outside his/her own experience.
- explain inverse and direct relationships of components in a system.

At **Late Formal** level pupils will begin or be able to:

- find proof for implicitly stated changes
- compare confirming and unconfirming details
- spontaneously see correlated relationship in a system.
- draw conclusions based upon implicitly stated changes.

8.9.3.7 PROPORTIONAL REASONING

(elevations in D/C)

At **Preoperational** level pupils will begin or be able to:

- develop concepts such as less, more, greater.
- identify an object when only one part is perceived.

At **Early Concrete** level pupils will begin or be able to:

- state simple relationships.
- describe common or different physical features in a design/component/setting.

At **Late Concrete** level pupils will begin or be able to:

- analysis simple comparative propositional relationships (good-bad)
- analysis simple relationships. (components and their functions)
- compare similar relationships that are explicitly stated.
- understand proportions in a design that are unidimensional.

At **Early Formal** level pupils will begin or be able to:

- explain reciprocal actions in a system.

8.9.3.8 FORMAL LOGIC

(fault tracing/testing)

At **Preoperational** level pupils will begin or be able to:

- explain solutions or problems in design technology.

At **Early Concrete** level pupils will begin or be able to:

- not to approach resolution of problems in design technology systematically by attributing to one factor or cause.

At **Late Concrete** level pupils will begin or be able to:

- state solution when details are provided.
- produce single inferences when details are explicitly stated.

At **Early Formal** level pupils will begin or be able to:

- summarise the theme of a project.
- produce inferences when information is implicitly stated.

At **Late Formal** level pupils will begin or be able to:

- describe conditional situation based upon the design.
- criticise and appraises other's style, setting, characterisation, theme context.
- generalise from one action to another.
- describe changes/transformations.

SECTION - 5 ~ RESULTS AND ANALYSES

CHAPTER - 9

RESULTS

9.1 GENERAL INTRODUCTION

In this chapter, the scores obtained from the tests administered to the pupils were presented for each of the year groups. A preliminary description of these results was first given. Thereafter, the scores were subjected to psychometric, qualitative, and simple developmental analyses. Whereas psychometric analysis involved identification of factors of technological thinking, qualitative analysis involved describing the factors identified and giving meaning to them, besides categorising the pupil's responses. Simple developmental analysis ended this part of the analysis, and involved describing how pupils thinking developed as they move up the year. The other part of the analysis concentrated on the design and technology curriculum (teaching and syllabuses) used in secondary schools, to see to what extent it was matched to the pupil's technological thinking.

Following the above outline, the treatment of data was as follows:

- The raw data which consisted of practical and written responses of pupils to design and technology tasks, were analysed for their cognitive level using SOLO taxonomy. Pupil's response level on the SOLO taxonomy was compared with their cognitive level on Piaget's formal reasoning task (Pendulum task).

-Both sets of responses were analysed amongst others, to find out whether categories of descriptors could be created for different cognitive levels of responses. These were organised into (or related to) developmental levels.

-Pupil's SOLO responses level and Pendulum tasks were compared to each other.

- From the literature review, eight appropriate Piagetian schema relating to design and technology were selected. They are classification, seriation, spatial ability, frame of reference, causality, correlational reasoning, proportional reasoning and formal logic.

-Design and technology curriculum and its cognitive level of demands were compared with the pupil's score on the Pendulum task.

9.2 RESULTS - 1 DATA PRESENTATION

9.2.1 MEAN SCORE, STANDARD DEVIATIONS FOR ALL THE TESTS AND YEAR GROUPS

In presenting these results some of tables and statistics results have been deliberately place in the appendix in order to free the text.

Tables-(1 to 4) show the mean scores and standard deviations for all tests, and all year group them combined. Scores from the three tests categories (design, manipulation and science thinking) were quite reasonably high for each of the year (see appendix-6) and combined groups. A high mean and standard deviation scores were noticed for manipulation tasks (MSRT, ACT) and design tasks (D1.2).

The histograms and line graphs for all the year groups combined reveal, amongst other things, that the sample group tended to use "unistructural/functional" category/strategy (D1.3usf) more often than "multistructual" category (D1.3ms). It was also noted, that the sample group tended to spend more time on the divergent thinking aspect of the task (ACDIV-TDIV), than on convergent thinking (ACCON - TCOM). The fault-tracing task (FT-TFT), also showed similar time consumption characteristics. These patterns were repeated to a lesser degree in each of the year groups when closely examined. (see histograms and line graphs for each year group in the appendix-6).

TABLE 1

THE MEAN AND STANDARD DEVIATION FOR ALL THE GROUPS

	Mean	Std Deviation	Variance	Col Sum %
ACCON	1.64	1.67	2.77	100.0%
ACDIV	1.91	1.77	3.14	100.0%
ACT	3.55	3.33	11.10	100.0%
D1.2	9.51	2.79	7.76	100.0%
D1.3	.35	.48	.23	100.0%
D1.3LLC	.64	.48	.23	100.0%
D1.2MS	.11	.31	.10	100.0%
D1.2USF	.88	.33	.11	100.0%
FT	.35	.48	.23	100.0%
MSR1	2.70	1.81	3.26	100.0%
MSR2	4.09	2.67	7.15	100.0%
MSR3	3.11	1.93	3.74	100.0%
MSR4	4.25	2.16	4.68	100.0%
MSRT	14.14	6.93	47.97	100.0%
PSL	2.09	.37	.14	100.0%
SCIREA	1.83	.93	.87	100.0%

(continued)

TABLE 2

A HISTOGRAM FOR ALL YEAR GROUPS COMBINED

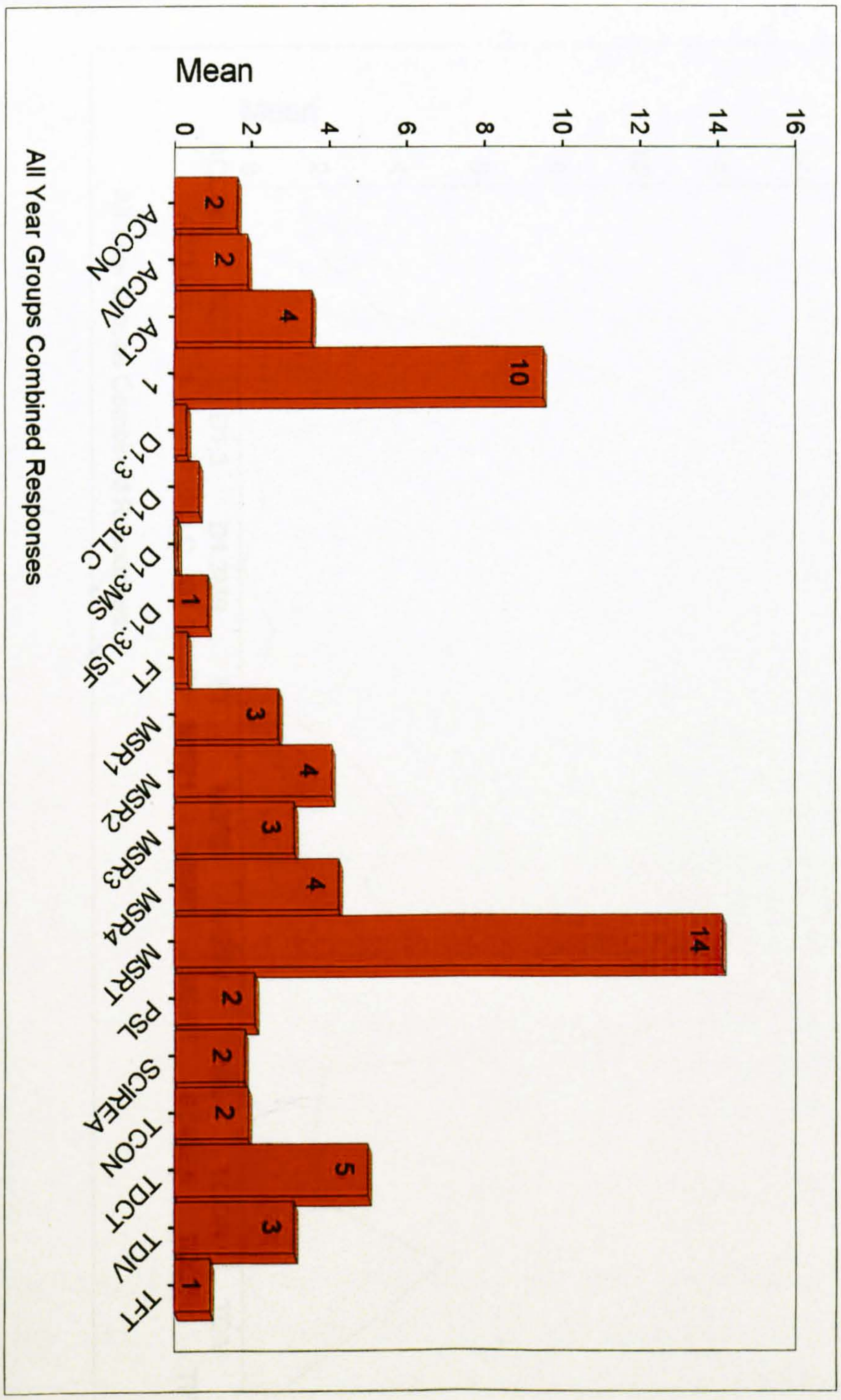
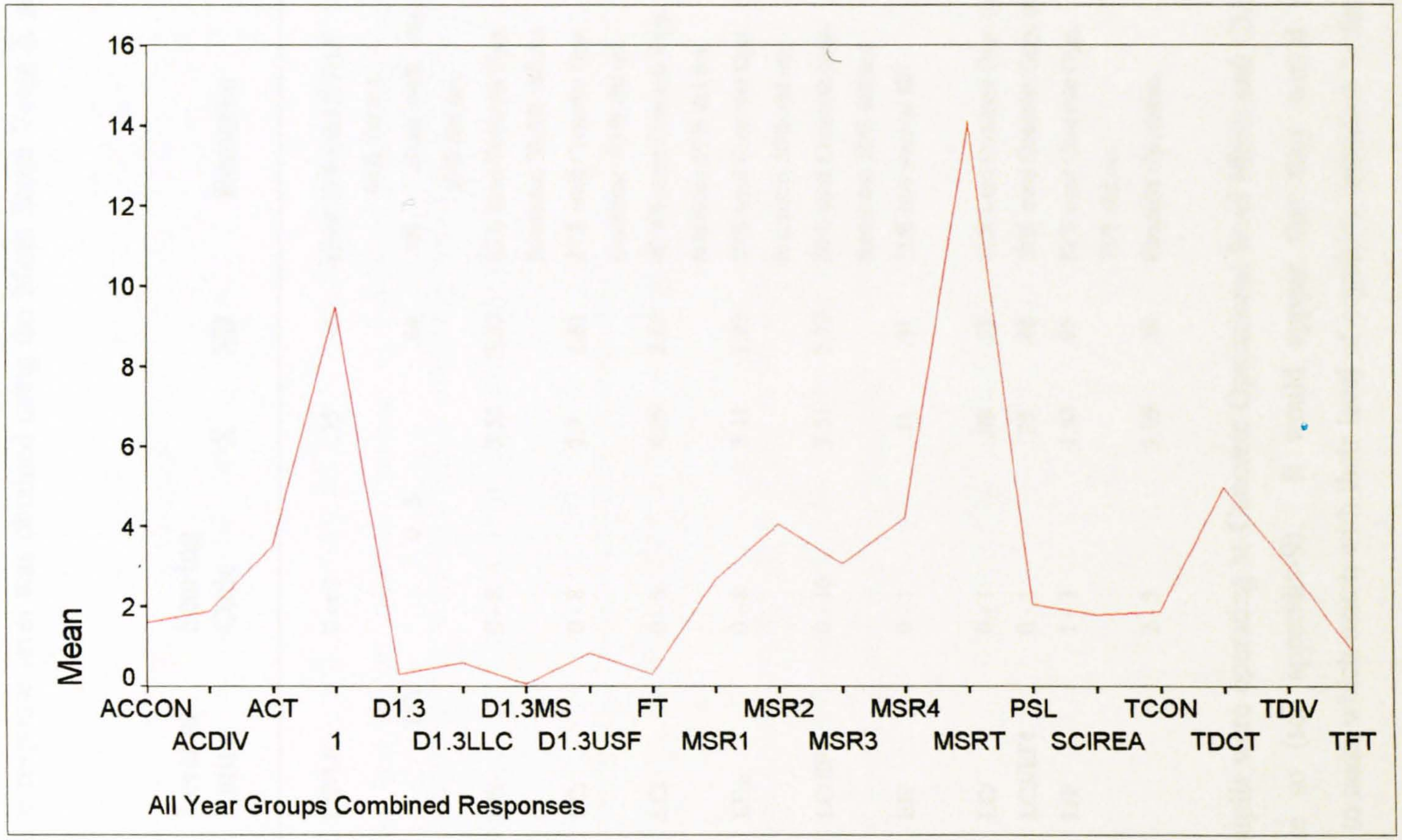


TABLE 3

LINE GRAPH FOR ALL THE YEAR GROUPS



9.3 PUPILS' COGNITIVE RESPONSE LEVEL (MEAN RESPONSE LEVEL)

Pupils cognitive response level was obtained using the Mean Score Value X and Chi-square values.

Category/ Tasks	Level of Rating	Scoring Code	X	SD	Remarks
D1.3	E/F/LF	0 or 1	.35	.48	about 35% used E/F/LF 65% did not.
D1.3LLC Op.	LC_3	0 - 3		.64	.48 about 64% used Concrete 36% did not.
ACT	LF_5	0 - 8	3.55	3.33	65% used Concrete Opp. functions; 35.5% did not
MSRI	LC_3	0 - 8	2.7	1.81	27% used Concrete Opp. functions; 73% did not.
MSR2	LC_3	0 - 8	4.09	2.62	40.9% used Concrete Opp. functions; 59% did not.
MRS2	$LF_{(5)}$	0 - 8	3.11	1.93	50% used Concrete Opp. functions; 50% did not.
D1.2	LC/EF	0 - 16	9.51	2.79	50% used Concrete Opp. functions; 50% did not.
D12.MS	EF/	0 - 1	.11	.31	11% less were at EF
D1.2 USF	LC/	0 - 1	.88	.33	88% used Concrete Opp. (match)
F/T	LC3/EF4	0 - 1	.35	.48	35% used Concrete Opp. (match)
Sci.Res.	L/F	1 - 3	1.83	.93	82% used Concrete Opp. 18% did not.
PSL		2 - 3	2.09	.39	Concrete Operation.

On average pupils were operating at Concrete Operational level Mean and Chi-square tables indicate so (see appendix-9). It would appear that they would respond appropriately to tasks which match with their level of cognitive operation or function.

The pupils' level of written responses from both practical and written tasks were analysed and arranged in five categories using SOLO taxonomy criteria (See the section on the instrument used) as the format.
The categories were coded as follows:-

No Response	=	0
Pre-Operational	=	1
Concrete Operations	=	2 - 3
Early Formal Operations	=	4
Late Formal Operations	=	5

Analysis of the data therefrom showed the pupils' Mean Cognitive level of responses to both practical and written tasks was translated as a multi-structural response. This was in concurrence with the score on Piaget's pendulum task which indicated that the majority of the pupils were at the concrete operational level of reasoning.

A sample of responses from pupils in each year group on task D1.2 is as presented below/overleaf. Note that the numbers in brackets are interpreted as follows:
(3/1), (2/0)
3 and 2 represent concrete operation as shown in the above table.
1 and 0 represent multistructural and unistructural responses according to the Structure of Observed learning outcome (SOLO).

RESPONSES TO TASK D1.2

KS3 (7)

25/3 (M)

1. Bad ---Because it is a bit too low (3/1)
2. Bad ---Because it might come off (3/1)
3. Bad ---Because someone might take some bits out
4. Good ---So you do not have to carry it around with you. (2/0)
5. Bad ---Because if someone was fixing their bike, they would only have one spanner.(2/0)
6. Bad ---Because you do not have any where to put it.(0/0)

7. Bad ---Less space for people (3/1)
8. Bad ---Because you might burn yourself.(3/1)
9. Bad ---No response (0/0)
10. Bad ---Too small to put ice-cream. (3/1)
11. Bad ---Because it is not too strong (3/1)
12. Bad ---It might catch fire (2/0)
13. Bad ---Too small. (3/1)
14. Good ---Can be used to cut wood. (2/0)
15. Bad ---Not too strong (3/1)
16. Good ---You can put your tea in (2/0)

26/4 (F)

1. Good ---It has a lot of balance.(3/1)
2. Good ---So you don't loose your ties (2/0)
3. Bad ---Because if it drops it will break (3/1)
4. Good ---It keeps your tapes neat. (2/0)
5. Bad ---It might be too big
6. Good ---Because if you loose your key you have to look for the star (2/0)
7. Good ---So you can travel. (2/0)
8. Bad ---Because the controls are too high and they might get hot and burn when touched. (3/1)
9. Good ---So you can use it to undo things.(2/0)
10. Bad ---Because the top is too small and you won't be able to get it out.(3/1)
11. Bad ---Because you don't know how strong it is. (3/1)
12. Good ---Because Good----Because you can sit comfortable beside the fire. (2/0)
13. Good ---So you can keep your books out of the way, (2/0)
14. Good ---So you can cut the things (2/0)
15. Bad ---All of the stuff will fall out. (2/0)
16. Bad ---Because the water will come out; because the spout is too low. (3/1)

9.4 CORRELATION

The data from the test results were examined for pattern of association and to tease out any factor(s) which underlined or accounted for the values of the variables. It was important to see whether the tests related to something else other than themselves.

All the tests administered to the pupils, were correlated, one with another. (See correlation co-efficient table-b). Clearly, although there were a few large correlation co-efficient values, many of the values recorded were small but statistically significant.

The Largest correlation co-efficient in the data matrix were as shown below.

Variables		**r**
ACCON with ACDIV	(A/C convergent and Divergent thinking)	.87
- ACT	(Combined Total Scores from A/C Conv. & A/C Div.)	.96
- TCON,TDIV,TDCT	(Time Variable)	.84, .83, .72
D1.2MS with Age 7	(Design thinking in Multi-Structural terms)	.40
MSR-2 with D1.2	(Design task - Spatial task (elevation))	.40
MSRT with D1.2	(Design task - All spatial, embedded test)	.45
FT with TFT	(Fault Tracing - Time)	.49
MSRI with MSR2	(Object Matching - Elevation)	.50
MSR3	(Object Matching - 3D)	.44
MSRT	(Object Matching - All spatial)	.69

Table-(a) Largest Correlation Coefficients

Convergent and divergent aspects of A/C performance tasks were highly correlated, so too were spatial ability tasks. The capacity to see a good design and to manipulate correlated to a value 0.4. The positive correlation from these and others showed on an ad hoc basis that there were positive associations between the scores of pupils within the group. This implied that any individual variations were derived from variations in a trait or process which underlies, to some extent, performance on the task.

Appendix-11 Correlation Coefficients

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- - Correlation Coefficients - -

	ACCON	ACDIV	ACT	AGE10	AGE7	AGE8	AGE9	BOY	D1.2	D1.3
ACCON	1.0000 (197) P= .	.8781 (197) P= .000	.9671 (197) P= .000	.2688 (197) P= .000	-.0012 (197) P= .987	-.5321 (197) P= .000	.3296 (197) P= .000	.0037 (197) P= .959	.1841 (197) P= .010	-.0225 (197) P= .754
ACDIV	.8781 (197) P= .000	1.0000 (197) P= .	.9710 (197) P= .000	.2932 (197) P= .000	.1008 (197) P= .159	-.5512 (197) P= .000	.2217 (197) P= .002	-.0213 (197) P= .766	.1609 (197) P= .024	.0113 (197) P= .875
ACT	.9671 (197) P= .000	.9710 (197) P= .000	1.0000 (197) P= .	.2903 (197) P= .000	.0530 (197) P= .459	-.5592 (197) P= .000	.2827 (197) P= .000	-.0095 (197) P= .894	.1776 (197) P= .013	-.0052 (197) P= .942
AGE10	.2688 (197) P= .000	.2932 (197) P= .000	.2903 (197) P= .000	1.0000 (197) P= .	-.2893 (197) P= .000	-.3039 (197) P= .000	-.2638 (197) P= .000	-.1609 (197) P= .024	.1771 (197) P= .013	.0536 (197) P= .454
AGE7	-.0012 (197) P= .987	.1008 (197) P= .159	.0530 (197) P= .459	-.2893 (197) P= .000	1.0000 (197) P= .	-.4069 (197) P= .000	-.3532 (197) P= .000	.1403 (197) P= .049	-.1596 (197) P= .025	.2622 (197) P= .000
AGE8	-.5321 (197) P= .000	-.5512 (197) P= .000	-.5592 (197) P= .000	-.3039 (197) P= .000	-.4069 (197) P= .000	1.0000 (197) P= .	-.3711 (197) P= .000	-.1053 (197) P= .141	.0110 (197) P= .878	-.3349 (197) P= .000
AGE9	.3296 (197) P= .000	.2217 (197) P= .002	.2827 (197) P= .000	-.2638 (197) P= .000	-.3532 (197) P= .000	-.3711 (197) P= .000	1.0000 (197) P= .	.1090 (197) P= .127	-.0026 (197) P= .971	.0356 (197) P= .619
BOY	.0037 (197) P= .959	-.0213 (197) P= .766	-.0095 (197) P= .894	-.1609 (197) P= .024	.1403 (197) P= .049	-.1053 (197) P= .141	.1090 (197) P= .127	1.0000 (197) P= .	-.0337 (197) P= .638	.0184 (197) P= .797
D1.2	.1841 (197) P= .010	.1609 (197) P= .024	.1776 (197) P= .013	.1771 (197) P= .013	-.1596 (197) P= .025	.0110 (197) P= .878	-.0026 (197) P= .971	-.0337 (197) P= .638	1.0000 (197) P= .	-.1186 (197) P= .097
D1.3	-.0225 (197) P= .754	.0113 (197) P= .875	-.0052 (197) P= .942	.0536 (197) P= .454	.2622 (197) P= .000	-.3349 (197) P= .000	.0356 (197) P= .619	.0184 (197) P= .797	-.1186 (197) P= .097	1.0000 (197) P= .
D1.3LLC	.0344 (197) P= .631	.0052 (197) P= .942	.0200 (197) P= .780	-.0660 (197) P= .357	-.2399 (197) P= .001	.3293 (197) P= .000	-.0419 (197) P= .559	-.0296 (197) P= .679	.1081 (197) P= .131	-.9672 (197) P= .000
D1.3MS	.0651 (197) P= .364	.1099 (197) P= .124	.0910 (197) P= .203	.0116 (197) P= .872	.4084 (197) P= .000	-.2259 (197) P= .001	-.1961 (197) P= .006	-.0077 (197) P= .915	.0428 (197) P= .550	.0952 (197) P= .183
D1.3USF	-.0154 (197) P= .830	-.0533 (197) P= .457	-.0361 (197) P= .615	.0107 (197) P= .881	-.4601 (197) P= .000	.2435 (197) P= .001	.2114 (197) P= .003	-.0405 (197) P= .572	-.0374 (197) P= .602	-.1213 (197) P= .090
FT	.0824 (197) P= .249	.1081 (197) P= .131	.0987 (197) P= .168	.2433 (197) P= .001	.0649 (197) P= .365	-.0154 (197) P= .829	-.2680 (197) P= .000	-.0346 (197) P= .630	.1785 (197) P= .012	.1608 (197) P= .024
GIRL	-.0037 (197) P= .959	.0213 (197) P= .766	.0095 (197) P= .894	.1609 (197) P= .024	-.1403 (197) P= .049	.1053 (197) P= .141	-.1090 (197) P= .127	-1.0000 (197) P= .000	.0337 (197) P= .638	-.0184 (197) P= .797
MSR1	.2795 (197) P= .000	.1991 (197) P= .005	.2456 (197) P= .001	.1805 (197) P= .011	-.3048 (197) P= .000	-.0082 (197) P= .909	.1666 (197) P= .019	-.0634 (197) P= .376	.3399 (197) P= .000	-.0927 (197) P= .195
MSR2	.2935 (197) P= .000	.2438 (197) P= .001	.2764 (197) P= .000	.0646 (197) P= .367	-.1007 (197) P= .159	-.1957 (197) P= .006	.2565 (197) P= .000	-.0239 (197) P= .739	.4228 (197) P= .000	.0085 (197) P= .905
MSR3	.2735 (197) P= .000	.2067 (197) P= .004	.2467 (197) P= .000	.2773 (197) P= .000	-.1635 (197) P= .022	-.2028 (197) P= .004	.1403 (197) P= .049	-.1171 (197) P= .101	.3848 (197) P= .000	-.0069 (197) P= .923
MSR4	.2465 (197) P= .000	.2067 (197) P= .004	.2332 (197) P= .001	.2038 (197) P= .004	-.2148 (197) P= .002	-.1077 (197) P= .132	.1579 (197) P= .027	-.1947 (197) P= .006	.2746 (197) P= .000	.0878 (197) P= .220
MSRT	.3463 (197) P= .000	.2899 (197) P= .000	.3273 (197) P= .000	.2368 (197) P= .001	-.2384 (197) P= .001	-.1686 (197) P= .018	.2181 (197) P= .002	-.1120 (197) P= .117	.4506 (197) P= .000	.0041 (197) P= .954
PSL	.1073 (197) P= .133	.1495 (197) P= .036	.1332 (197) P= .062	.0348 (197) P= .627	.2498 (197) P= .000	-.1509 (197) P= .034	-.1310 (197) P= .066	-.0621 (197) P= .386	.0454 (197) P= .527	.0609 (197) P= .395
SCIREA	.2425 (197) P= .001	.2011 (197) P= .005	.2282 (197) P= .001	.0149 (197) P= .836	-.0671 (197) P= .349	-.1529 (197) P= .032	.2199 (197) P= .002	.0281 (197) P= .695	.0067 (197) P= .925	.1119 (197) P= .118
TCON	.8440 (197) P= .000	.8363 (197) P= .000	.8668 (197) P= .000	.2022 (197) P= .004	.0710 (197) P= .322	-.5468 (197) P= .000	.3292 (197) P= .000	-.0171 (197) P= .812	.1412 (197) P= .048	.0290 (197) P= .686
TDCT	.8346 (197) P= .000	.8827 (197) P= .000	.8868 (197) P= .000	.2722 (197) P= .000	.0652 (197) P= .363	-.5528 (197) P= .000	.2793 (197) P= .000	.0320 (197) P= .655	.0978 (197) P= .172	.0590 (197) P= .410
TDIV	.7620 (197) P= .000	.8432 (197) P= .000	.8295 (197) P= .000	.2882 (197) P= .000	.0654 (197) P= .362	-.5146 (197) P= .000	.2242 (197) P= .002	.0568 (197) P= .428	.0619 (197) P= .388	.0774 (197) P= .280
TFT	.2035 (197) P= .004	.2193 (197) P= .002	.2184 (197) P= .002	.3283 (197) P= .000	.0814 (197) P= .255	-.1374 (197) P= .054	-.2307 (197) P= .001	.0993 (197) P= .165	.0785 (197) P= .273	.2382 (197) P= .001

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- - Correlation Coefficients - -

	D1.3LLC	D1.3MS	D1.3USF	FT	GIRL	MSR1	MSR2	MSR3	MSR4
ACCON	.0344 (197) P= .631	.0651 (197) P= .364	-.0154 (197) P= .830	.0824 (197) P= .249	-.0037 (197) P= .959	.2795 (197) P= .000	.2935 (197) P= .000	[illegible]	.2465 (197) P= .000
ACDIV	.0052 (197) P= .942	.1099 (197) P= .124	-.0533 (197) P= .457	.1081 (197) P= .131	.0213 (197) P= .766	.1991 (197) P= .005	.2438 (197) P= .001	[illegible]	.2067 (197) P= .004
ACT	.0200 (197) P= .780	.0910 (197) P= .203	-.0361 (197) P= .615	.0987 (197) P= .168	.0095 (197) P= .894	.2456 (197) P= .001	.2764 (197) P= .000	[illegible]	.2332 (197) P= .001
AGE10	-.0660 (197) P= .357	.0116 (197) P= .872	.0107 (197) P= .881	.2433 (197) P= .001	.1609 (197) P= .024	.1805 (197) P= .011	.0646 (197) P= .367	[illegible]	.2038 (197) P= .004
AGE7	-.2399 (197) P= .001	.4084 (197) P= .000	-.4601 (197) P= .000	.0649 (197) P= .365	-.1403 (197) P= .049	-.3048 (197) P= .000	-.1007 (197) P= .159	[illegible]	-.2148 (197) P= .002
AGE8	.3293 (197) P= .000	-.2259 (197) P= .001	.2435 (197) P= .001	-.0154 (197) P= .829	.1053 (197) P= .141	-.0082 (197) P= .909	-.1957 (197) P= .006	[illegible]	-.1077 (197) P= .132
AGE9	-.0419 (197) P= .559	-.1961 (197) P= .006	.2114 (197) P= .003	-.2680 (197) P= .000	-.1090 (197) P= .127	.1666 (197) P= .019	.2565 (197) P= .000	.1403 (197) P= .049	.1579 (197) P= .027
BOY	-.0296 (197) P= .679	-.0077 (197) P= .91	-.0405 (197) P= .572	-.0346 (197) P= .630	-1.0000 (197) P= .000	-.0634 (197) P= .376	-.0239 (197) P= .739	-.1171 (197) P= .101	-.1947 (197) P= .006
D1.2	.1081 (197) P= .131	.042 (197) P= .55	-.0374 (197) P= .602	.1785 (197) P= .012	.0337 (197) P= .638	.3399 (197) P= .000	.4228 (197) P= .000	.3848 (197) P= .000	.2746 (197) P= .000
D1.3	-.9672 (197) P= .000	.095 (197) P= .18	-.1213 (197) P= .090	.1608 (197) P= .024	-.0184 (197) P= .797	-.0927 (197) P= .195	.0085 (197) P= .905	-.0069 (197) P= .923	.0878 (197) P= .220
D1.3LLC	1.0000 (197) P= .	-.083 (197) P= .24	.1083 (197) P= .130	-.1581 (197) P= .027	.0296 (197) P= .679	.0630 (197) P= .379	-.0193 (197) P= .788	-.0078 (197) P= .913	-.1028 (197) P= .151
D1.3MS	-.0633 (197) P= .245	1.0000 (197) P= .	-.9274 (197) P= .000	.0912 (197) P= .203	.0077 (197) P= .915	-.0887 (197) P= .215	.0628 (197) P= .380	.1088 (197) P= .128	.0661 (197) P= .356
D1.3USF	.1083 (197) P= .130	-.9274 (197) P= .000	1.0000 (197) P= .	-.0519 (197) P= .469	.0405 (197) P= .572	.0931 (197) P= .193	-.0694 (197) P= .332	-.0840 (197) P= .240	-.0569 (197) P= .427
FT	-.1581 (197) P= .027	.0912 (197) P= .203	-.0519 (197) P= .469	1.0000 (197) P= .	.0346 (197) P= .630	.0748 (197) P= .296	-.0437 (197) P= .542	.0698 (197) P= .330	.0912 (197) P= .203
GIRL	.0296 (197) P= .679	.0077 (197) P= .91	.0405 (197) P= .572	.0346 (197) P= .630	1.0000 (197) P= .	.0634 (197) P= .376	.0239 (197) P= .739	.1171 (197) P= .101	.1947 (197) P= .006
MSR1	.0630 (197) P= .379	-.088 (197) P= .21	.0931 (197) P= .193	.0748 (197) P= .296	.0634 (197) P= .376	1.0000 (197) P= .	.5019 (197) P= .000	.4490 (197) P= .000	.3421 (197) P= .000
MSR2	-.0193 (197) P= .788	.062 (197) P= .38	-.0694 (197) P= .332	-.0437 (197) P= .542	.0239 (197) P= .739	.5019 (197) P= .000	1.0000 (197) P= .	.6169 (197) P= .000	.4936 (197) P= .000
MSR3	-.0078 (197) P= .913	.108 (197) P= .12	-.0840 (197) P= .240	.0698 (197) P= .330	.1171 (197) P= .101	.4490 (197) P= .000	.6169 (197) P= .000	1.0000 (197) P= .	.6034 (197) P= .000
MSR4	-.1028 (197) P= .151	.066 (197) P= .35	-.0569 (197) P= .427	.0912 (197) P= .203	.1947 (197) P= .006	.3421 (197) P= .000	.4936 (197) P= .000	.6034 (197) P= .000	1.0000 (197) P= .
MSRT	-.0249 (197) P= .728	.052 (197) P= .46	-.0443 (197) P= .537	.0624 (197) P= .383	.1120 (197) P= .117	.6947 (197) P= .000	.8492 (197) P= .000	.8200 (197) P= .000	.7679 (197) P= .000
PSL	-.0530 (197) P= .460	.844 (197) P= .00	-.6197 (197) P= .000	.1152 (197) P= .107	.0621 (197) P= .386	-.0822 (197) P= .251	.0231 (197) P= .748	.1069 (197) P= .135	.0484 (197) P= .500
SCIREA	-.0939 (197) P= .189	.028 (197) P= .68	-.0358 (197) P= .618	.2051 (197) P= .004	-.0281 (197) P= .695	.1025 (197) P= .152	.1125 (197) P= .116	.1094 (197) P= .126	.1130 (197) P= .114
TCON	-.0192 (197) P= .789	.0250 (197) P= .727	.0227 (197) P= .751	.0905 (197) P= .206	.0171 (197) P= .812	.2536 (197) P= .000	.2745 (197) P= .000	.2017 (197) P= .004	.1884 (197) P= .008
TDCT	-.0472 (197) P= .510	.0269 (197) P= .708	.0236 (197) P= .742	.0900 (197) P= .208	-.0320 (197) P= .655	.2470 (197) P= .000	.2456 (197) P= .001	.1894 (197) P= .008	.2210 (197) P= .002
TDIV	-.0652 (197) P= .363	.0248 (197) P= .730	.0235 (197) P= .743	.0836 (197) P= .243	-.0568 (197) P= .428	.2174 (197) P= .002	.2050 (197) P= .004	.1614 (197) P= .023	.2164 (197) P= .002
TFT	-.2234 (197) P= .002	.048 (197) P= .49	-.0482 (197) P= .502	.4905 (197) P= .000	-.0993 (197) P= .165	.0777 (197) P= .278	-.0336 (197) P= .639	.0928 (197) P= .194	.1203 (197) P= .092

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- - Correlation Coefficients - -

	MSRT	PSL	SCIREA	TCON	TDCT	TDIV	TFT
ACCON	.3463 (197) P= .000	.1073 (197) P= .133	.2425 (197) P= .001	.8440 (197) P= .000	.8346 (197) P= .000	.7620 (197) P= .000	.2035 (197) P= .004
ACDIV	.2899 (197) P= .000	.1495 (197) P= .036	.2011 (197) P= .005	.8363 (197) P= .000	.8827 (197) P= .000	.8432 (197) P= .000	.2193 (197) P= .002
ACT	.3273 (197) P= .000	.1332 (197) P= .062	.2282 (197) P= .001	.8668 (197) P= .000	.8868 (197) P= .000	.8295 (197) P= .000	.2184 (197) P= .002
AGE10	.2368 (197) P= .001	.0348 (197) P= .627	.0149 (197) P= .836	.2022 (197) P= .004	.2722 (197) P= .000	.2882 (197) P= .000	.3283 (197) P= .000
AGE7	-.2384 (197) P= .001	.2498 (197) P= .000	-.0671 (197) P= .349	.0710 (197) P= .322	.0652 (197) P= .363	.0654 (197) P= .362	.0814 (197) P= .255
AGE8	-.1686 (197) P= .018	-.1509 (197) P= .034	-.1529 (197) P= .032	-.5468 (197) P= .000	-.5528 (197) P= .000	-.5146 (197) P= .000	-.137 (197 P= .05
AGE9	.2181 (197) P= .002	-.1310 (197) P= .066	.2199 (197) P= .002	.3292 (197) P= .000	.2793 (197) P= .000	.2242 (197) P= .002	-.230 (197 P= .00
BOY	-.1120 (197) P= .117	-.0621 (197) P= .386	.0281 (197) P= .695	-.0171 (197) P= .812	.0320 (197) P= .655	.0568 (197) P= .428	.09 (19 P= .1
D1.2	.4506 (197) P= .000	.0454 (197) P= .527	.0067 (197) P= .925	.1412 (197) P= .048	.0978 (197) P= .172	.0619 (197) P= .388	.07 (19 [illegible]
D1.3	.0041 (197) P= .954	.0609 (197) P= .395	.1119 (197) P= .118	.0290 (197) P= .686	.0590 (197) P= .410	.0774 (197) P= .280	.2 [illegible]
D1.3LLC	-.0249 (197) P= .728	-.0530 (197) P= .460	-.0939 (197) P= .189	-.0192 (197) P= .789	-.0472 (197) P= .510	-.0652 (197) P= .363	-.2 [illegible]
D1.3MS	.0527 (197) P= .462	.8442 (197) P= .000	.0288 (197) P= .688	.0250 (197) P= .727	.0269 (197) P= .708	.0248 (197) P= .730	.0 [illegible]
D1.3USF	-.0443 (197) P= .537	-.6197 (197) P= .000	-.0358 (197) P= .618	.0227 (197) P= .751	.0236 (197) P= .742	.0235 (197) P= .743	-.0 [illegible]
FT	.0624 (197) P= .383	.1152 (197) P= .107	.2051 (197) P= .004	.0905 (197) P= .206	.0900 (197) P= .208	.0836 (197) P= .243	.4 [illegible]
GIRL	.1120 (197) P= .117	.0621 (197) P= .386	-.0281 (197) P= .695	.0171 (197) P= .812	-.0320 (197) P= .655	-.0568 (197) P= .428	[illegible]
MSR1	.6947 (197) P= .000	-.0822 (197) P= .251	.1025 (197) P= .152	.2536 (197) P= .000	.2470 (197) P= .000	.2174 (197) P= .002	[illegible]
MSR2	.8492 (197) P= .000	.0231 (197) P= .748	.1125 (197) P= .116	.2745 (197) P= .000	.2456 (197) P= .001	.2050 (197) P= .004	[illegible]
MSR3	.8200 (197) P= .000	.1069 (197) P= .135	.1094 (197) P= .126	.2017 (197) P= .004	.1894 (197) P= .008	.1614 (197) P= .023	[illegible]
MSR4	.7679 (197) P= .000	.0484 (197) P= .500	.1130 (197) P= .114	.1884 (197) P= .008	.2210 (197) P= .002	.2164 (197) P= .002	[illegible]
MSRT	1.0000 (197) P= .	.0328 (197) P= .648	.1444 (197) P= .043	.3025 (197) P= .000	.3160 (197) P= .000	.2928 (197) P= .000	[illegible]
PSL	.0328 (197) P= .648	1.0000 (197) P= .	.0136 (197) P= .849	.0747 (197) P= .297	.0793 (197) P= .268	.0751 (197) P= .294	[illegible]
SCIREA	.1444 (197) P= .043	.0136 (197) P= .849	1.0000 (197) P= .	.2618 (197) P= .000	.2733 (197) P= .000	.2629 (197) P= .000	[illegible]
TCON	.3025 (197) P= .000	.0747 (197) P= .297	.2618 (197) P= .000	1.0000 (197) P= .	.9243 (197) P= .000	.8090 (197) P= .000	[illegible]
TDCT	.3160 (197) P= .000	.0793 (197) P= .268	.2733 (197) P= .000	.9243 (197) P= .000	1.0000 (197) P= .	.9711 (197) P= .000	[illegible]
TDIV	.2928 (197) P= .000	.0751 (197) P= .294	.2629 (197) P= .000	.8090 (197) P= .000	.9711 (197) P= .000	1.0000 (197) P= .	[illegible]
TFT	.0843 (197) P= .239	.0198 (197) P= .783	.2759 (197) P= .000	.2142 (197) P= .003	.2692 (197) P= .000	.2832 (197) P= .000	[illegible]

(Coefficient / (Cases) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

9.5 FACTOR ANALYSIS

To identify any underlying 'structure' among the variables and describe them psychologically, factor analytic procedure was utilized. Factor Analysis using varimax rotation in 6 iterations produced six (6) factors (see factor maxtrix below)

VARIMAX converged in 6 iterations.

Rotated Factor Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
ACT	.95231	.16362	.05343	-.04506	.01820	.05524	.03484
TDCT	.94958	.11826	-.01895	.03399	-.02125	.07936	.08256
ACDIV	.93886	.11864	.07783	-.02925	.03133	.07786	-.00820
TCON	.91338	.13011	-.00756	.00955	.01688	.01579	.10911
ACCON	.90585	.20104	.02405	-.05900	.00305	.02764	.07843
TDIV	.90025	.09329	-.02404	.05081	-.04060	.11254	.06191
AGE8	-.64380	-.06333	-.21928	-.45303	.11248	.10898	.08788
MSRT	.18834	.95983	.00451	.03884	.04995	-.00524	.05024
MSR3	.11347	.82936	.08625	.04055	.06916	.03638	-.01805
MSR2	.16208	.82054	.05233	.05401	-.06142	-.17797	.02781
MSR4	.10999	.72785	.02076	.13593	.19357	.04418	.09159
MSR1	.14828	.68045	-.16347	-.11925	-.00024	.06635	.07500
D1.2	.04898	.57613	.03308	-.20095	-.05660	.20268	-.11875
D1.2MS	.03106	.05278	.97491	.02169	.01629	.04318	.01946
D1.2USF	.01687	-.05184	-.91510	-.07828	.05095	-.02554	.01668
PSL	.08006	.02720	.83863	-.04278	.09927	.04876	.06404
AGE7	.12078	-.31902	.54044	.32331	-.18959	-.00829	-.24464
D1.3LLC	.00900	-.00449	-.03776	-.95413	.00505	-.11495	-.04386
D1.3	.00685	-.02281	.05381	.95338	.00617	.11985	.05835
BOY	.01668	-.06873	-.00390	.01391	-.98529	-.00479	.02260
GIRL	-.01668	.06873	.00390	-.01391	.98529	.00479	-.02260
TFT	.19736	.03241	-.00255	.18193	-.12874	.76790	.16062
FT	.02602	.05002	.07795	.07444	.01935	.76585	.19027
AGE9	.30952	.19203	-.24550	.11494	-.09991	-.59191	.46829
AGE10	.28210	.23463	-.09578	.03435	.19994	.54391	-.34414
SCIREA	.20382	.06066	.02599	.06398	-.01439	.20936	.82469

9.5.1 FACTORS AND THEIR DESCRIPTION

Factor 1: **General Intelligence/Cognitive Ability Factor**

This is an IQ or general ability-type factor; all divergent and convergent components/elements of A/C performance tests loaded heavily on this factor. This factor also has most of the sub-scale test positively loading on it although not heavily.

The first factor, composed of Variables ACDIV, TDIV (divergent thinking), Variables ACCON, TCON (convergent thinking), seemed to be a straight-forward General Intelligence, or IQ/General Ability-type factor.

Variable ACDIV, TDIV was divergent thinking, and this type of thinking has been known to encapsulate other types of thinking, e.g. scientific thinking, mathematical thinking, etc., because of its very nature. Thus, it was not altogether surprising that this variable correlates positively with other variables. Furthermore, this Variable (divergent thinking), appears to spread its importance between two dimensions; ie. it contributes to two other abilities.

Thus, it could be called a mixed factor. Variable ACCON, TCON (convergent thinking), as another dimension of creativity, was in some ways related to that aspect of general intelligence (ability), concerned with the pupils' focusing their thinking on a particular principle or characteristic (e.g. colour or size), which they had decided upon as relevant to the grouping of the blocks of wood. Indeed, each of the dimensions of creativity in technology, ie. "divergent" thinking (Variable ACDIV, TDIV) [the pupils' capacity to range flexibly in search for relevant principles or characteristics with which to group the blocks of wood], and "convergent" thinking (Variable ACCON, TCON), as described above, were often identifiable as intellectual abilities.

The science thinking task (Variable - SCIREA) performed by the pupils, had divergent and convergent elements. The pupils, in doing this task were required to sort out the effects of three variables viz. length, weight, and push.

They presumably went through phases of exploration (divergent thinking), then analysis, and finally synthesis (convergent thinking). All these can be identified with general intelligence.

Therefore, it was not out of place to say that much of what Variable -ACDIV, TDIV (divergent thinking), Variable - TCON, ACCON (convergent thinking), Variable - SCIREA (science reasoning) involved was very much the traditional definition of intelligence; ie. perceiving relationships between elements in a general sort of way.

It is a bit surprising, however, that divergent thinking is actually an element of this factor (g), although some people have found that this is quite common. As a very broad dimension, no one is particularly sure how useful it is to have divergent thinking. Nevertheless, it has been found in this particular factor.

Divergent (Variable - ACDIV, TDIV) and convergent (Variable - ACCON, TCON) elements of the task are complementary characteristics of "effective" thinking. The latter, can be identified with the broader conception of intelligence. (Guilford 1950, 1954; Hudson, 1956, 1958).

Briefly, this thinking involves the capacity to range flexibly or diverge in search for relevant factors in connection with a particular matter being dealt with and the capacity to focus or converge one's thinking regarding whatever factors that have been decided upon as relevant.

As implied above, divergent thinking was concerned with the production of ideas, and the test which was administered to the pupils required them to produce different (novel) responses in relation to things. Presented with an object, e.g. transistor, the pupils produce concepts associated with the object, and subsequently, are able to relate them to the object within the appropriate context.

Thus, in producing ideas from thinking about the different uses to which an object can be put, the ability to perceive relationships was vital, just as it was vital when putting them together. Clearly, as dimensions of the creative aspect of technology, divergent thinking was concerned with the exploration and production of ideas, whereas, convergent thinking was related to "synthesis" i.e. focusing of thought or putting ideas together.

Divergent thinking (Variable - ACDIV, TDIV), because of its very nature, permeated other kinds of thinking, including scientific thinking, mathematical thinking, etc. Thus, in science, traces of both divergent and convergent thinking abound. However, convergent thinking was known to be closely associated with science thinking and IQ as "definiteness", "precision", and the like, were qualities or characteristics of IQ, and science. Convergent thinking as described above, in science and A-C performance task administered to the pupils, exhibited similar qualities or characteristics.

Thus, pupils who were "good" at synthesising might be said to exhibit intellectual abilities in effect. To be a "good" synthesiser, one was required as a necessity to possess a certain degree of ability to analyse. After all, synthesis presupposes analysis, and in technology, as well as science, this was not an exception. In fact, tasks (A-C performance) were administered to the pupils which demanded the understanding of the whole structure, and bringing together ideas etc., which in effect presumed analysis.

It can therefore be said that the "creativity" involved in designing and making, required the powers of analysis (in the above sense) and synthesis. Here, the elements of intelligence began to surface, and underlined the fact that technological thinking involves some creativity and some 'intelligence'. The relationship between creativity and intelligence has already been mentioned.

Furthermore, the manipulation of a system task (Variable - FT, trouble shooting, or similar tasks e.g. assembling or disassembling), presumed analysis. The surface visualisation tasks (Variables MSR, 1, 2, 3 and 4) showing the plan of the artefact or object was analytical in some respects. By means of isometric projection, the three (3) views or elevations of the object, could be brought together (synthesised) in their appropriate relationship.

In an attempt merely to underline the importance of "synthesis" in design and making, which after all, is what 'IQ'. is about, (bringing things together, connecting things etc.), it was not out of place to say that, therein, the power of synthesis appeared to be more important than that of analysis. In some cases, this called for knowledge of causal relations and properties of the elements involved. Indeed, as the demand for higher knowledge of causal relations and properties of elements involved became apparent, there was a gradual move towards the domain of scientific explanation.

The pupils' development of the above mentioned qualities appeared to be linked to their stage development level. This was apparent by examining the tasks that the pupils were asked to do. Task or Variable - SCIREA (science thinking test), required the pupils to show the ability to sort out the effects of three variables, viz. length, weight and push of the pendulum, on the period of oscillation. As the length of the pendulum was the only important factor, the pupils were required to overcome what Wylam and Shayer (1978, p.9) called "strong intuitive feeling", to realise this by actually constructing or designing experiments which controlled the appropriate variables, and deducing therefrom, the effect of length.

In tasks or Variables - ACDIV, TDIV (divergent thinking) and - ACCON, TCON (convergent thinking), the pupils were also required to sort sixteen blocks of wood into various groups using particular sorting principles, some of which were given, and others not given. By being able to "sort" things out in the tests mentioned above, the pupils were inextricably isolating, juxtaposing, categorising and combining concepts, dimensions, etc., besides co-ordinating activities. It was therefore not difficult to discern the kinds of mental processes or ability involved in isolating, juxtaposing, combining and categorising etc. They would include perceptual discrimination, classification, categorisation and differentiation.

These abilities appeared to be necessary if the pupils were to be able to relate, say, technological components to their functions, or length of the pendulum to the period of oscillation. The mental disposition of the pupils described above ran parallel with the psychological description of the characteristics of the pupils in Piagetian terms (between stage 2B and 3A/3B), as Variable - PSL indicated. This factor is regarded as essentially a "cognitive" factor.

9.5.2 Factor 2: Spatial/Perceptual (Visual) Analysis

Clearly all the MSR sub-scale tests are heavily loaded on this factor.

In tasks/variables MSR 1 - 4 (see correlation matrix table-b), the pupils had to manipulate images. In this task, spatial-visualisation ability appear to have been used.

The fact that design tasks D1.2 correlated with manipulation tasks MSR1-2 was not surprising, but confirmatory of the important role of spatial-visualisation ability in design and making activity.

Thus, by looking at the variables (or tasks) composing this factor MSR1-4, it was not difficult to judge most of them as primarily visual.

The importance of visual dimension of technological thinking cannot be over-emphasised. The pupils' conception of technology appears to be a function of their level of perception or perceptual analysis.

Generally speaking, our ideas are engendered firstly by our faculty of perception and, secondly, by that of conception. This factor, and the elements composing it, seemed to suggest that pupils first of all have to develop to a reasonable level the ability to perceive objects visually, before they can be in a position to think of them meaningfully in technological terms, or form ideas about them. It was therefore not totally out of place to designate visual perception as the starting-point of any meaningful technological thinking for the pupils. In fact, the significantly high correlation coefficients between elements of this factor appear to support this assertion.

Perceptual analysis appeared to be linked to the development of the ability to discriminate, differentiate and co-ordinate. For instance, for the pupils to be able to arrive at the conclusion that a particular object, as in Variable D1.2, was a design distinct from objects not designed, or that an artefact was a "bad" or "good" design, some form of discrimination must be deployed.
In Variables MSR1-4 (see correlation matrix table-b), where the pupils had to choose a correct views from a number of similarly drawn views, the ability to discriminate seemed to be an aid to success in this activity. Furthermore, when they were engaged in the activity of causing the light to work, as in Variable - FT (fault tracing), the ability to discriminate appeared to have prevented them from making the wrong connections, e.g. putting the yellow plugs into the blue sockets, or a blue plug into a yellow socket. Another interesting point concerned the relationship between the pupils' capacity to see a good design and their capacity to manipulate objects.

Remember, that manipulation tasks used here involve Variables -MSR1 - 4 (see correlation matrix table-b).

Variable D1.2 was a measure of pupils' capacity to see a good or bad design. This capacity, is expressed in either uni- or multi-structural reasons.

For instance, a uni-structural response to item -1 in test D1.2, ie. whether or not the table shown is a good design, would be:-

"Good. ~ resting things on."

"Good. ~ because it is stable."

"Good. ~ because it is firm."

And a multi-structural response to the same item would be:-

"Good. ~ it's got a flat top and it looks sturdy."
"Good. ~ it is strong and could hold a heavy weight."
"Good. ~ stable and sturdy good structure."

The correlation matrix (see table-b), shows that Variables D1.2 correlated with Variables MSR1 - 4, suggesting some relationship between the pupils' capacity to manipulate and their capacity to see a "good" or "bad" design. Although, this relationship (.40/45) is not very strong, nevertheless, it is significant, and appeared to be reciprocal. This partly meant that when the capacity to see a good or bad design was expressed in terms of uni-structural reason, the capacity to manipulate tended to be less, but improved when the former capacity was expressed in terms of multi-structural reasons. Thus, the relationship appeared to be reciprocal, such that to be able to see a good design, the pupils would have to manipulate dimensions (such as size, weight, height, shape, colour, etc.), of the object or design in some ways.

For pupils to be able to judge a design as either "bad" or "good", it appeared that they would mentally rotate, and visualise the artefact from all conceivable perspectives, and at the same time, take a number of factors into account or consideration. Consequently, the significant correlation between the reasons the pupils gave for judging either way, good or bad, (Variable D1.2), and the range of manipulation tasks, namely, mental rotation of objects MRS1, mental visualisation of three dimensional figures or surfaces MSR 2 and 3 respectively and divergent thinking (Variable ACDIV), seem to suggest that the capacity to see a good or bad design, may be linked to their ability to manipulate objects.

9.5.3 Factor 3: Design Thinking Style

This factor seems to represent design thinking style i.e. multi-structural and uni-structural/functional. Although Bi-Polar, Piaget's stage level also loaded heavily on this factor. Design categorisation D1.3 MS and D1.3 USF, all loaded heavily on this factor.

From the correlation matrix (see table-b), Variable D1.2 USF (thinking in terms of function), negatively correlates with Variable D1.2 MS (thinking in terms of structures), but, positively correlates with Variable PSL (Piaget's stage development levels).

It is however important to remember, that Variables D1.2 USF, D1.2 MS, PSL were dimensions on which Test D1.2 (Design test) was scored, namely, functional/uni-structural (Variable D1.2 USF), structural/multi-structural (Variables D1.2 MS). Here are some instances of each dimension:

> "Functional" responses to the design task which requires the pupils to say whether the artefact no.1 (see Task D1.2) is a good or bad design are thus:
>
> "Good. ~ It is some where to sit and drink" (Yr. 8)
> "Good. ~ because you would not have to put everything on the floor,
> ~ kick them over. (Yr. 9)
> "Good. ~ because it is usual to put things on." (Yr. 10)
> "Good. ~ It is good so that you can put your coffee or tea on the table instead of the floor." (Yr. 11).

Typical "Structural" responses to the same task are:

> "Good. ~ It's got a flat top and looks sturdy". (Yr. 7)
> "Good. ~ Because it is rectangle and does not fall over (stable)". (Yr. 8)

"Good. ~ It is strong and could hold a heavy weight". (Yr. 9)

"Good. ~ Because it is stable and strong". (Yr. 10)

"Good. ~ Stable and sturdy good structure". (Yr. 11)

These scoring dimensions emerged from the pupils' own response pattern.

To reiterate, whereas Variable D1.2 MS is a measure of 'structure', and corresponds to adults' responses, Variable D1.2 USF, is a measure of function, and corresponds to how children respond. Clearly, this factor is a bi-polar (positive and negative), function/structure categorisation. and this seems to correspond to the sort of categorisation arrived at by Bruner, Olver and Greenfield et. al. (1966), when they looked at applications and divided them into 'function' and 'structure'.

Function/Structure (Bi-polar) Element - What is Function and Structure?

At face value, it was surprising that technological thinking was not associated with understanding of the functional aspect. Why must this be so? When we come to think about technology, do we not think in terms of functions? It was rather odd here that this was not the case, particularly, as one would expect those pupils who are good at technological thinking to have a very good grasp of function.

Thus, one possible way of looking at or interpreting these results, could be in terms of the superficiality of the bi-polarity of structure. In other words, although 'structure' was something which was opposed to 'function', ie. bipolar, nevertheless, this was on the surface only. By closely examining the nature of pupils' functional and structural responses to the tests administered, there appeared not to be any such opposition between the two dimensions. In fact, there are instances, where the pupils used a combination of both dimensions at the same time in their responses as to whether or not the picture of the artefacts shown in test D1.2 is good.

Examples of their responses to item -1 of D1.2 are as follows:-

"Good. ~ Good for putting cups of tea on because it is square." (Yr. 8)

"Good. ~ It is strong and could hold a heavy weight." (Yr. 9)

"Good. ~ Basic design, but strong and serves its purpose." (Yr. 11)

An examination of the functional responses given by the pupils of all year groups, showed that they were quite low levels. It should be noted at this juncture that pupils were given scores where they responded in terms of what they can do with the objects shown (see test D1.2), more or less in a very concrete kind of way, thus, making the functional response a concrete operational kind of response. This was of course not a response that could throw out the whole functional response. It is an immediate concrete operational response. Here are selected examples of their responses to item -15 of test D1.2:

"Good. ~ moves things easily." (Yr. -7)

"Good. ~ you can put things in it instead of carrying them." (Yr. -8)

"Good. ~ a wheel-barrow is handy because human arms can only carry a little." (Yr. -9)

"Good. ~ for moving items (heavy) eg. garden materials." (Yr. -10)

"Good. ~ transports things easily to short distances." (Yr. -11).

In another test requiring the pupils to design something that could carry a hand camera to a specific height above their school for an aerial photograph of the school, some of their responses were more or less immediate: eg. "Just take yourself and the camera up in a helicopter." (Yr. -7) "Scaffolding" "crane" (yr. -8) "Use a plane or a helicopter" (Yr. -10).

From these responses, it could be implied that perhaps, what structure means here, is an understanding of function in a more comprehensive way. And responses to item -15 of test D1.2 such as:

"Good. ~ you can fit more in a wheel-barrow than in your hands."

(Yr. -7)

"Bad. ~ when you wheel it, all the rubbish will come out." (Yr. -8)

"Bad. ~ should have two wheels; bigger wheels." (Yr. -9)

"Bad. ~ when you lift it up, the much will run out of the font." (Yr. -10)

"Bad. ~ loading, a problem from rear end, back to high, could tip up." (Yr. -11);

and also responses to the aerial photography task, such as, or which amount to, "Describing a balloon which uses scientific principles to lift the camera to a height above the school". (Yr. -8) "Using pulleys and ropes to take the camera and self to the top of the school building". (Yrs. -9, -10, and -11), seem to support this view.

Since Variable D1.2 USF (thinking in terms of function) negatively correlates with the rest of the variables, it can be concluded that the "good" end of the bipolar factor, was the "structural" end. The implication of this was well borne out when the developmental analysis was done. This factor can be identified with cognitive style.

9.5.4 Factor 4: <u>Practical Ability</u>

This factor is concrete, very practical in nature. This is <u>'practical'</u> ability. Design tasks D1.3 and D1.3 LLC loaded heavily on this factor.

9.5.5 Factor 5: <u>Logical/Systematic Thinking</u>

This factor seems to suggest some logical/systematic thinking in concrete terms. The fault-tracing task loaded heavily on this factor. This factor seemed to share some of the characteristics of Factor 2 in that, when manipulating a system as in trouble-shooting in a faulty system (Fask FT), besides knowing the names of the control knobs etc., the pupils were expected to know their locations and how they are spatially related.

9.5.6 Factor 6: <u>Science Thinking</u>

This factor was related to science reasoning suggesting that technology thinking includes scientific thinking but is not determined by it.

It is worth stating here that factor analytic techniques do have inherent limitations. One such limitation is the restriction on the number of variables which can be included in tests. Such that, if one added another set of tests, then a different set of results, or another factor, would emerge. In other words, the more tests one added to the analysis, the more factors that would be extracted. Due to this limitation, caution has been exercised in discussing the above results.

It was also interesting to note the relationship amongst the factors. (See factor trans-function matrix table-d)

F1 negatively related with others and positively with self
F2 positively related with F2, F3, F4 and self
F3 positively related with F6 and self
F4 positively related with F3 and self
F5 positively related with F2, F3 and self
F6 positively related with F1, F3, F4, F5 and self.

These factors are related to the schema identified in some important ways, in that the schema could be found operating within each factor.

Factor Transformation Matrix:

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1	.86792	.46019	.06920	.08421	.01775
Factor 2	-.26743	.66313	-.54294	-.34483	.24201
Factor 3	-.35792	.49482	.70013	.20276	.22143
Factor 4	-.15945	.10776	-.42521	.77854	-.14415
Factor 5	.10627	-.28869	-.12708	-.06810	.79388
Factor 6	-.06107	.05389	-.00673	-.45126	-.48071
Factor 7	-.08147	-.07607	.11510	-.13597	.09988

	Factor 6	Factor 7
Factor 1	.10877	.10447
Factor 2	-.12537	.02779
Factor 3	.20078	-.08002
Factor 4	.36491	.14863
Factor 5	.49040	-.11763
Factor 6	.74529	-.05610
Factor 7	.05504	.97100

Hi-Res Chart # 2:Factor plot of factors 1, 2, 3

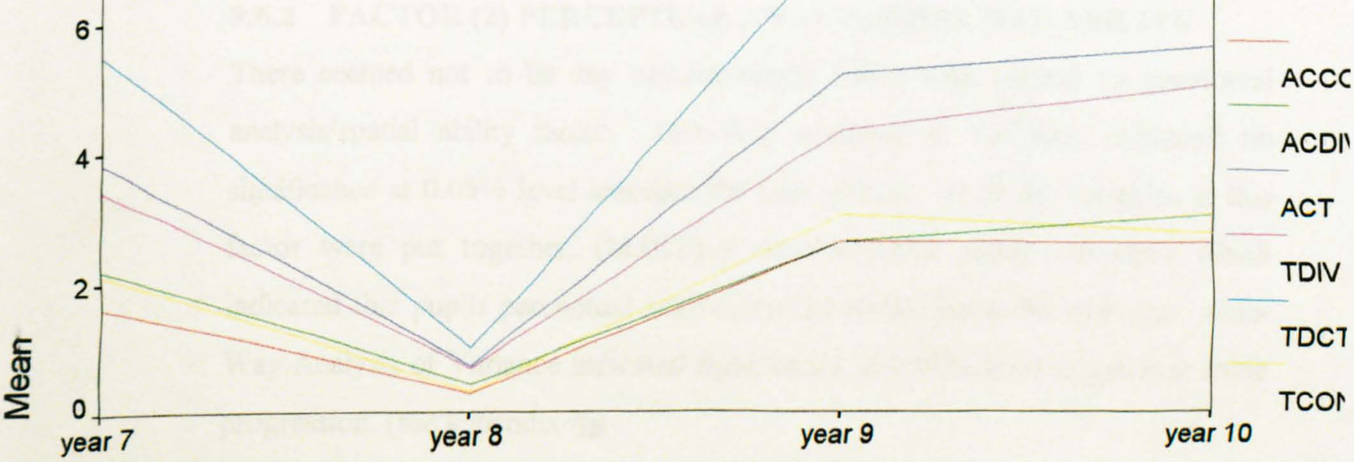
9.6 DEVELOPMENTAL ANALYSIS

Having identified and described the meaning of the factors elicited by means of factor analysis, I find that the development of abilities (or developmental analysis) becomes much easier. Through such analysis the sort of changes that take place with increasing age of the pupils can become apparent. In other words, the interest here is in pupils' developmental pattern, particularly, as data have been collected from different age groups.

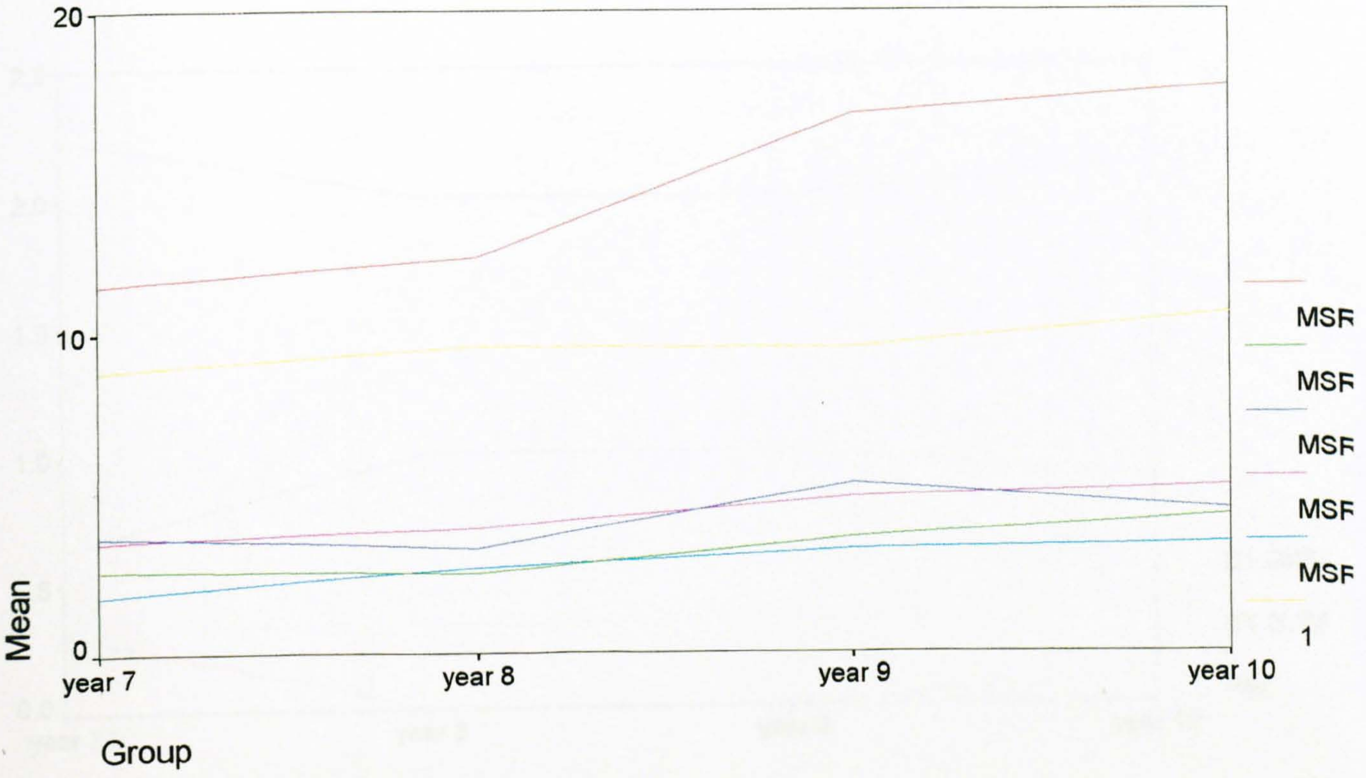
Thus, what follows is, or represents, an account of the increase, stability, or decrease, in pupils' test scores over the age range under investigation.

This is done by plotting a graph of mean (grand) scores against the different year groups for each of the identified factors. Indeed, it is expected that some tests would be more interesting than others in terms of pupils' responses.

9.6.1 FACTOR (1) - GENERAL INTELLIGENCE/ABILITY



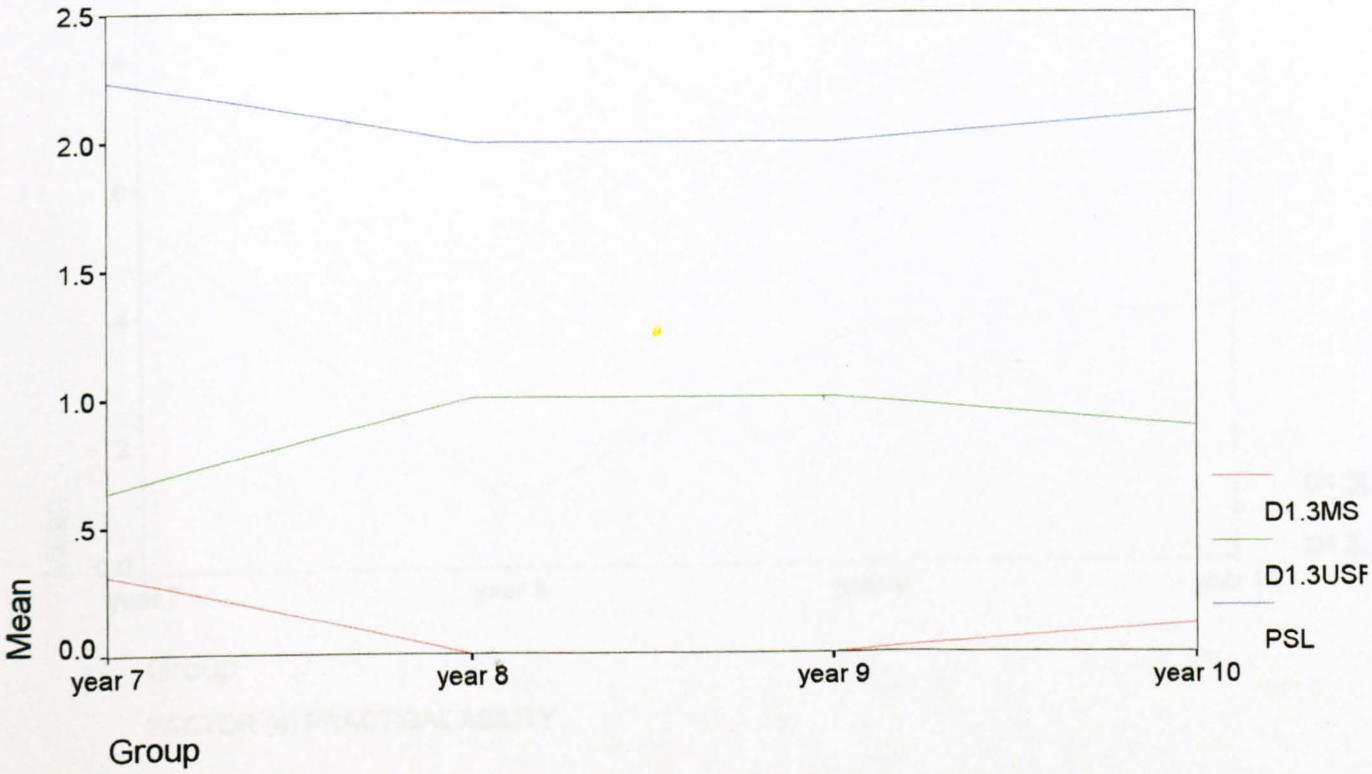
FACTOR (1) GENERAL INTELLIGENCE/ABILITY



FACTOR (2) PERCEPTUAL ANALYSIS/SPATIAL ABILITY

9.6.2 FACTOR (2) PERCEPTUAL ANALYSIS/SPATIAL ABILITY

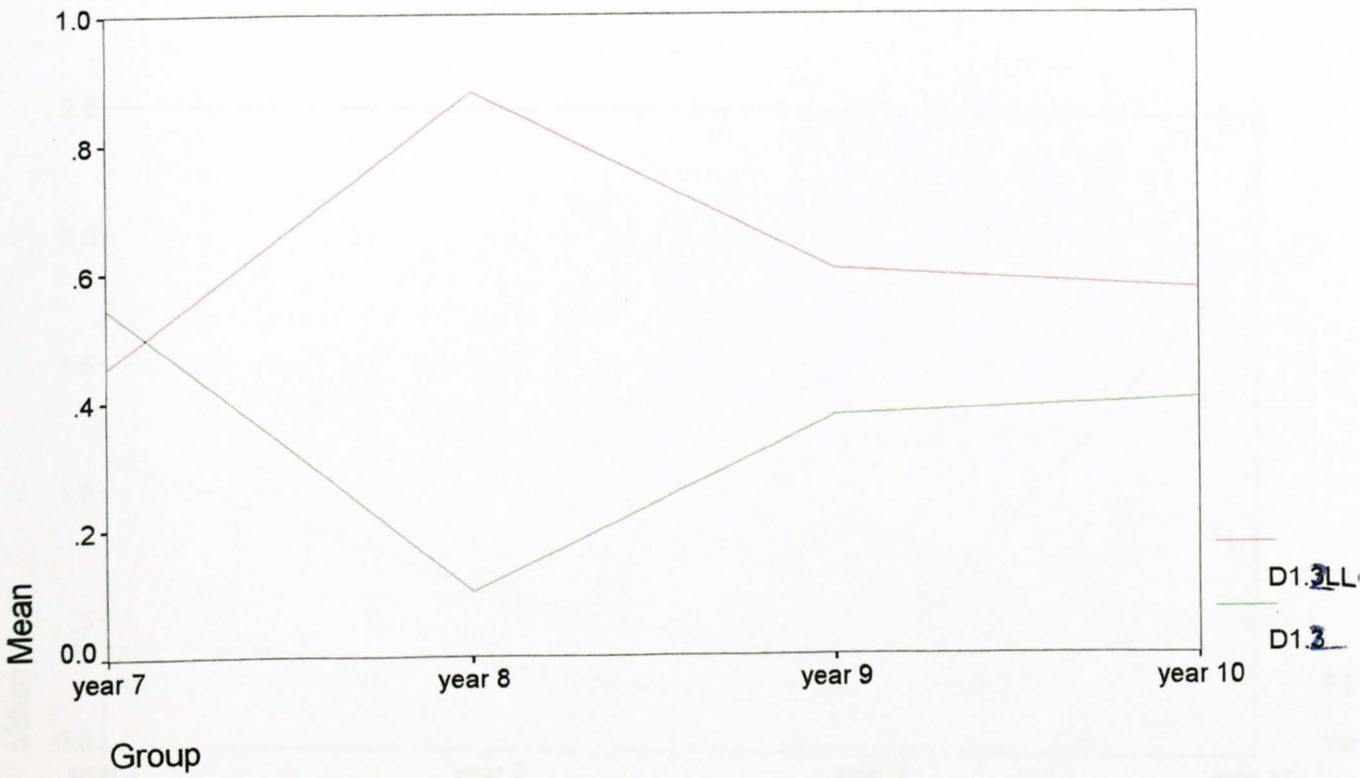
There seemed not to be any developmental trends with respect to perceptual analysis/spatial ability factor. One-Way Analysis of Variance, indicated no significance at 0.05% level amongst the year groups. If all the variables in this factor were put together, (MSRT) a developmental pattern emerged which indicated that pupils perceptual analysis/spatial ability increased with age. One-Way Analysis of Variance indicated significance at 0.01% level suggesting some progression. (see appendix-13)



FACTOR (3) FUNCTION/STRUCTURE

9.6.3 FACTOR (3) FUNCTIONS/STRUCTURE

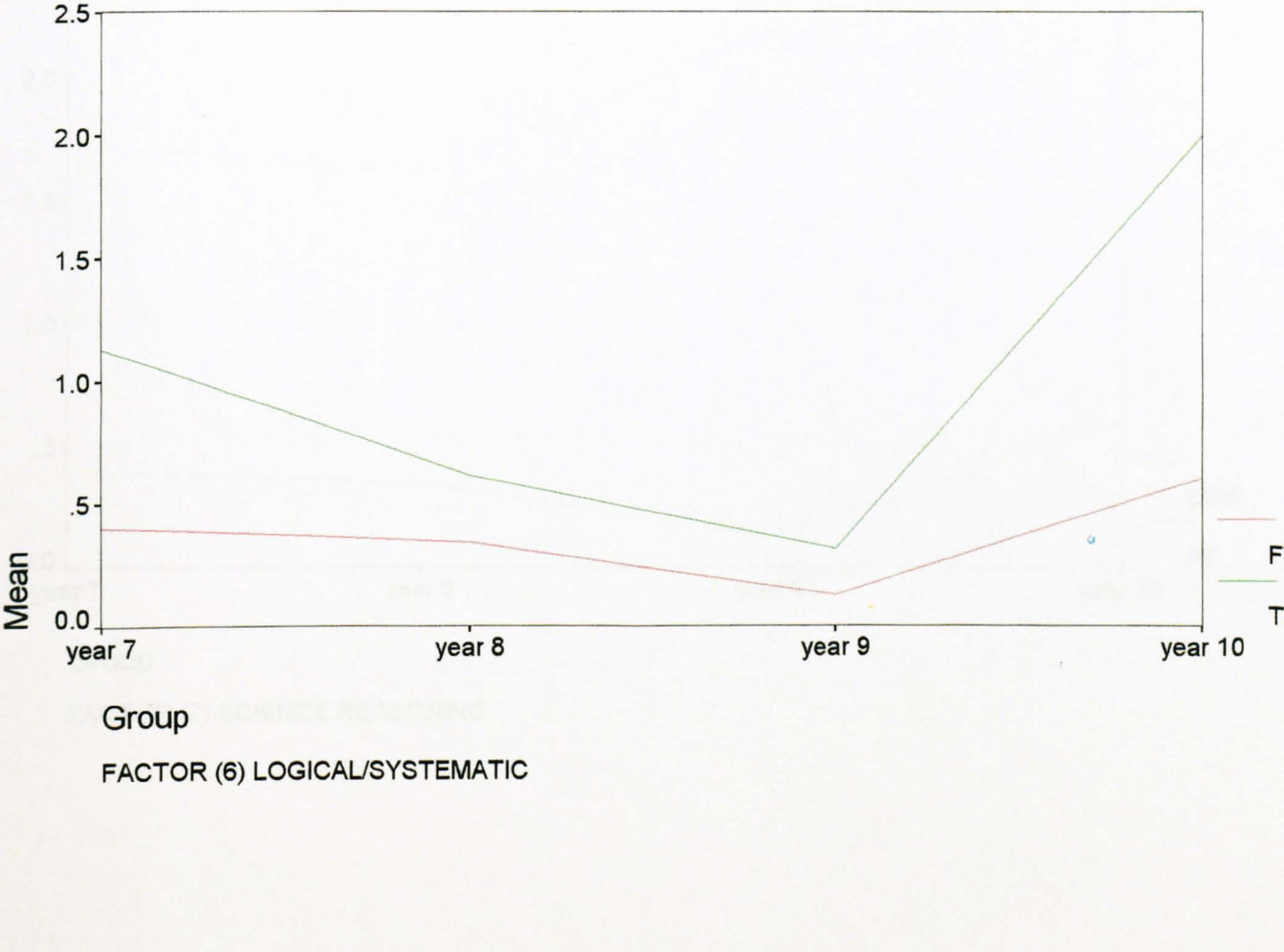
With this factor, whereas 'Multi-Structural' thinking showed some decreases during the early years. 'Uni-structural'/functional' thinking increased and levelled off at during the later years. One-Way analysis of Variance showed significance level between the groups Year 7 and Year 8. (see appendix-13c) At Year 9, 'Multi-structural' began showing signs of increase. It would appear that, pupils think first in 'functional'/'uni-structural' terms, then slowly moved towards 'structural' terms.



FACTOR (4) PRACTICAL ABILITY

9.6.4 FACTOR (4) PRACTICAL ABILITY

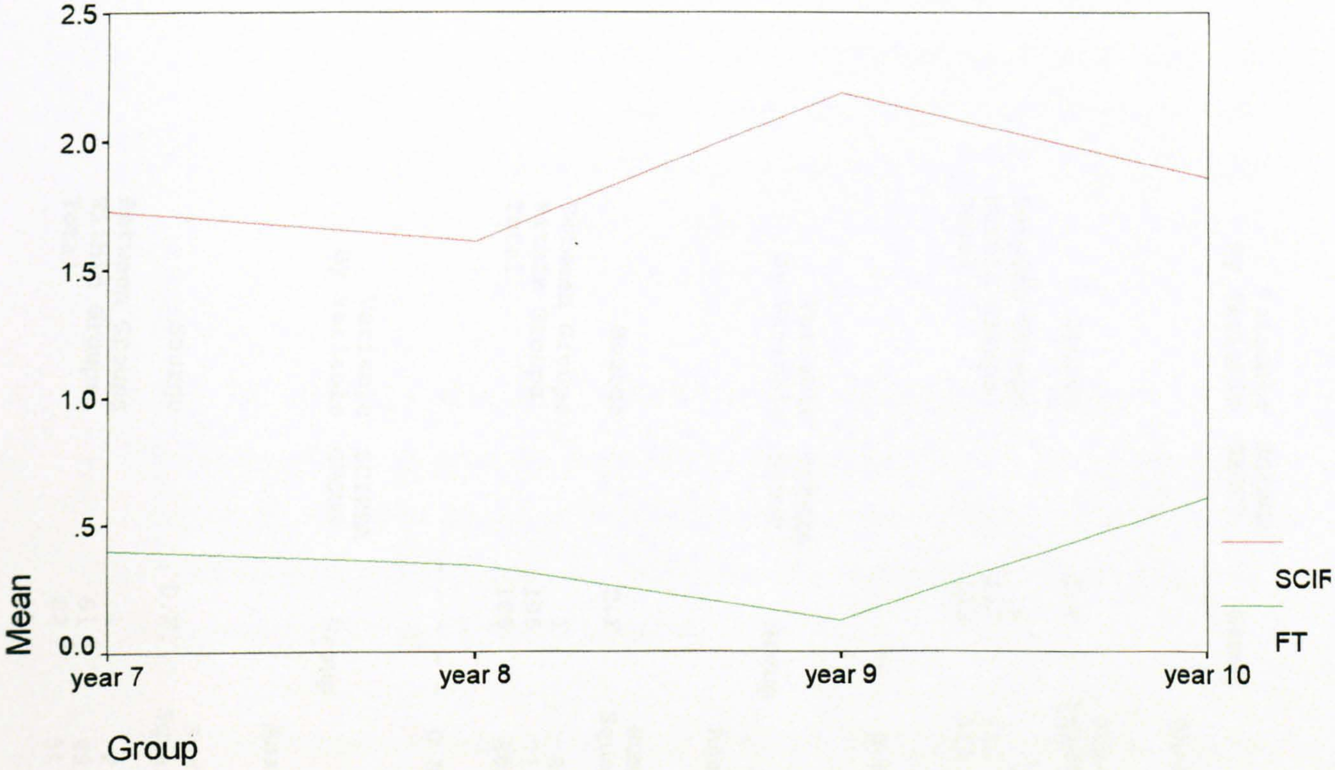
There was an increased use of 'practical' ability during the earlier years, up to Year 8. One-Way Analysis of Variance showed signficant differences at 0.01% level. (see appendix-13d) Thereafter, it dipped slightly and stabilized during the later years. This seemed to support the outcome described for Factor (3).



FACTOR (6) LOGICAL/SYSTEMATIC

9.6.5 FACTOR (6) LOGICAL/SYSTEMATIC

There was a somewhat gradual drop in the use of systematic/logical thinking until about Year 9. One-Way Analysis of Variance showed no significant difference at 0.05% level. (see appendix-13e) Thereafter, logical/systematic thinking began to increase. Further evidence suggest that pupils during the earlier years tend to 'repeat' actions (operations) illogically. As they progress through the years, these operations/
actions become systematic, logical.



FACTOR (7) SCIENCE REASONING

9.6.6 FACTOR (7) SCIENCE REASONING

This showed clear developmental patterns. The deployment of this thinking in technology work increased with age and tended to fall slightly after Year 9. The differential use of this thinking was not significant between the groups as indicated by the result of the One-Way Analysis of Variance.(see overleaf p.)

----- O N E W A Y -----

Variable SCIREA
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.3903	.3903	.3941	.5314
Within Groups	112	110.9430	.9906		
Total	113	111.3333			

----- O N E W A Y -----

Variable SCIREA
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	8.8218	8.8218	12.9830	.0005
Within Groups	105	71.3464	.6795		
Total	106	80.1682			

----- O N E W A Y -----

Variable SCIREA
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	2.2090	2.2090	3.6076	.0611
Within Groups	81	49.5982	.6123		
Total	82	51.8072			

SUMMARY

The above developmental analysis has pinpointed times/periods when certain characteristics exhibited by pupils can be harnessed to fit in with the curriculum being delivered. The analysis shows that during the early years, children tended to repeat action (operation) illogically; i.e. without being able to explain the action. However, as they progress through the years, their operation (action) becomes increasingly systematic (logical). This fits in with Piaget's developmental model. Teaching design and technology should begin with some activity (action) and then progress to more sophisticated levels.

9.7 TECHNOLOGICAL THINKING - (An Empirical Definition)

The conclusion drawn from the structures or factors identified by the use of Factor Analysis, in relation to the definition of technological thinking is that, what is termed as "technological thinking" here, and judged by these tests results, seemed to have six components typified by the factors identified.

Thus, "technological thinking" is that type of thinking in which the above six factors featured prominently, and perhaps other factors which were yet to be identified.

It is not however, largely accounted for in terms of Piagetian scientific thinking because as clearly indicated, the first factor is not defined by Piagetian tasks. Nevertheless, Piagetian tasks formed one aspect of the tests, and it is apparent that other tests added to it providing further useful information e.g. the test of structural applications, test of visual analysis.

9.8 CURRICULUM ANALYSIS - (THE APPLICATION OF DESIGN AND TECHNOLOGY TAXONOMY)

The pupils were administered Piagetian pendulum test to ascertain their cognitive reasoning level. The results from the data collected indicated that a large percentage (70%) of the subjects sampled were at Concrete Operational level of reasoning.

Important aspects of the National Curriculum design and technology were analysed separately for their cognitive demands. Each cognitive level was given a value which was related to the SOLO value level. The value levels are as presented below:

<u>COGNITIVE LEVELS AND THEIR VALUES</u>

Pre-Operational Level	=	1
Concrete Operational Level	=	2
Late Concrete Operational Level (LC)	=	3
Early Formal Operation (EF)	=	4
Late Formal Operation (LF)	=	5

It will be recalled that the literature review section on contextual analysis identified some of the schemata needed for understanding design and technology subject area for example, classification and seriation abilities. By reflecting on the objectives as stated in the National Curriculum design and technology, and from my own familiarity with Piaget's protocol, further schemata were identified. They include proportional and correlational reasoning, spatial/visual ability, causality, and frame of reference.

After the schemata have been identified, the next step in determining the cognitive demands of design and technology subject is to read though the objectives as stated in the National Curriculum design and technology. For instance, at key stage 3, one of the designing skills component objectives requires the pupils to (a) *'develop a specification for their product'*

This objective clearly asks pupils to *categorise, classify (list ideas)*. As the pupils are engaged in this task they are also presumably *evaluating* which piece of idea should be included on the list of their specifications. Evaluation in this context is a component of Bloom's taxonomy of cognitive aspect of knowledge. According to the table in section-6 *evaluation* relates to *late formal* operation in Piagetian protocol. Details of late formal operation were examined in section -2 of this thesis. The design and technology taxonomy attempts to describe the range of possible responses within design and technology subject demanded (or expected) of pupils (or which they are able to produce). From the example cited, mapping shows that pupils at this level are expected hypothetically to elaborate on details of the specifications aspect of the project. Further examples are shown in tables (e) and (f) overleaf, of how the curriculum objectives in design and technology (designing and making skills) have been analysed using the taxonomy developed for this investigation. When all the objectives under the designing skills component of the National Curriculum have been analysed, the average of the different level is obtained. This represents the level of cognitive demand made by this aspect of the design and technology curriculum.(see tables on pages 263 to 268

Tables (e), (f) : Showing how design and technology taxonomy is (or can be) used to assess the demands on (or the thinking of) the pupils as well as analyse the curriculum.

Table (e)

NC d&t Objectives (pupils are to be taught to):	Piaget's Schemata required to understand tasks	Piaget's level/ (read taxonomy for a range of ability for particular level)	Bloom's Protocol	Structure of Observed-learning outcomes (SOLO)
KS3 Designing skills				
(a) identify appropriate sources of information that will help with their designing	Classification; Categorisation	Late formal (read d&t taxonomy for a range of ability for this level)	Evaluation	5
(b) use design briefs to guide design thinking.	frame of reference	Early formal (read d&t taxonomy for a range of ability for this level)	Application	4
(e) generate design proposals that match stated design criteria and modify proposals to improve them	Proportional reasoning	Late formal (read d&t taxonomy for a range of ability for this level)	Evaluation	5
(g) take account of the working characteristics and properties of materials and components when deciding how and when to use them	Correlational reasoning	Early concrete (read d&t taxonomy for a range of ability for this level)	Knowledge	2
(h) prioritise and reconcile decisions on materials and components, production, time and costs within design proposals.	Order/Seriation	Late formal (read d&t taxonomy for a range of ability for this level)	Evaluation	5

(I) take account of the restrictions imposed by the capacities and limitations of tools and equipment.	Proportional reasoning (working within limits)	Early concrete (read d&t taxonomy for a range of ability for this level)	Knowledge	2
(k) develop a clear idea of what has to be done and propose an outline plan, which include alternative methods of proceeding if things go wrong.	Classification/Seriation/ Spatial ability.	Early formal. (read d&t taxonomy for a range of ability for this level)	Application	4
KS4. (f) to determine the degree of accuracy required for the product to function as planned, taking account of critical dimensions and tolerances in determining methods of manufacture.	Correlational (relationship/Inequality)	Early formal. (read d&t taxonomy for a range of ability for this level)	Application	4
(h) how graphic techniques,.....can be used in a variety of ways to model aspects of design proposals and assist in making decisions.	Spatial ability	Early formal (read d&t taxonomy for a range of ability for this level)	Application	4
(I) to produce and use detailed working schedules that will achieve the desired objectives and provide alternatives to possible problems	Seriation ability	Early formal (read d&t taxonomy for a range of ability for this level)	Application	4

Table (f)

KS3 Making skills (pupils are to be taught to:	Piaget's Schemata required to understand tasks	Piaget's Level/ (d & t taxonomy)	Bloom's Protocol	Structure of Observed learning Outcome (SOLO)
(a) use a range of processed to shape and form material, including forming by wastage, attachment, adhesion and combining.	Seriation ability	Early formal (read d&t taxonomy for a range of ability for this level)	Application	4
(b) select materials, tools and equipment appropriate to the task	Classification ability	Late concrete/(read d&t taxonomy for a range of ability for this level)	Knowledge	2
(d) join and combine additional materials and components accurately in temporary and permanent ways.	Correlational ability	Early formal (read d&t taxonomy for a range of ability for this level)	Analysis/Applicat-ion	3&4
(f) interconnect a variety of components to achieve functional results	Correlational ability	Early formal (read d&t taxonomy for a range of ability for this level)	Application	4
KS4 (h) to produce and use detailed working schedules that will achieve the desired objectives, setting realistic deadlines for various stages of manufacture, identifying critical points in the making process and providing alternatives to	Seriation ability	Late formal (read d&t taxonomy for a range of ability for this level)	Evaluation	5

possible problems.				

Summary of both KS 3&4 design and technology curriculum analysis using the design and technology taxonomy is presented in the tables (g,h,i) below.

Curriculum Analysis and Mean Cognitive Level

Table-(g): Cognitive Schema necessary for the understanding of the concepts/work in Design Technology used in this investigation and the Mean Cognitive level required for each aspect.

Aspects of D&T	**Schemata (d&t taxonomy)**	**Levels/Values (SOLO)**	**Mean Cognitive Level (MCLDT)**
KS3 Designing Skills	Classification (LF)	5	
	Frame of Reference (LC) EF	3/4	
	Proportional Reasoning (LC)	3	
	Correlational Reasoning (EC)	4	X = 4 (E/F)
	Seriation (L/F)	5	
	Spatial /Temporal/Visuo (EF)	4	
Making Skills	Seriation (E/F)	4	
	Classification (L/C)	3	
	Correlational (E/F)	4	X= 3.6 (L/C -E/F)
	Proportional Reasoning (LC)	3	
	Spatial-Temporal (E/F)	4	
Material & Components	Causality (LF)	5	
	Classification (LC)	3	X = 4 (E/F)
	Correlational Reasoning (E/F)	4	
Systems & Control	Classification (E/F)	4	
	Correlational Reasoning (E/F)	4	X = 4 (E/F)
	Seriation (E/F)	4	
Structure	Proportional Reasoning (L/C)	3	
	Spatial-Temporal (L/C)	3	X=3.6 (L/C)
	Classification (E/F)	5	

Key: LC - Late Concrete 3
EF - Early Formal 4
LF - Late Formal5
MCLDT - Mean Cognitive Level of Design & Technology.

Table-(h): Cognitive Schema necessary for the understanding of the concepts/work in Design Technology used in this investigation and the Mean Cognitive level required for each aspect.

Aspects of D&T	Schemata (d&t taxonomy)	Levels/Values (SOLO)	Mean Cognitive Level (MCLDT)
KS4	Classification (LC)	3	
	Frame of Reference (E/F)	4	
Designing Skills	Proportional Reasoning (LC)	3	
	Correlational Reasoning (EF)	4	X = 3.6
	Seriation (E/F)	4	(LC/EF)
	Spatial (EF)	4	
Making Skills	Seriation (L/F)	5	
	Classification (L/C)	3	
	Correlational (L/C)	3	X= 3.8 (L/C -E/F)
	Proportional Reasoning (E/F)	4	
	Spatial-Temporal/Visuo (E/F)	4	
	Frame of Reference (L/F)	4	
Material & Components	Causality (L/C)	3	
	Spatial-Temporal (E/F)	4	X = 3.7
	Correlational Reasoning (E/F)	4	
	Seriation (E/F)	4	(L/C)
Systems & Control	Correlational Reasoning (E/F)	4	
	Seriation (E/F)	4	X = 4 (E/F)
	Spatial-Temporal/Visuo (E/F)	4	
Products/Applications	Correlational (E/F)	4	
	Spatial-Temporal/Visuo (E/F)	4	X=4 (E/F)
	Classification (E/F)	4	

Key: LC - Late Concrete 3
EF - Early Formal 4
LF - Late Formal5
MCLDT
- Mean Cognitive Level of Design & Technology.

TABLE-(I): SUMMARY OF THE MEAN RESPONSE VALUES OF PUPILS' COGNITIVE LEVEL

MEAN SCIENCE REASONING	COGNITIVE MEAN PIAGET	PUPILS' MEAN COGNITIVE LEVEL (PMCRL) (derived from tasks designed for this investigation)	DESIGN AND TECHNOLOGY CURRICULUM (MCLDT)	DIFFERENCE BETWEEN PMCRL & MCLDT
1.83	2.09	**Design Tasks** — **Level** D1.3 = 2.75 - c D1.3 LCC = 3.00 - lc D1.2 = 3.50 -lc/ef D1.2 MS = 3.00 - lc D1.2 USF = 3.00 –lc X = 3.05 – c	**Design** KS3 & KS4 X = 3.8 - lc/ef	0.75
		Making ACT = 3.55 - ef MSR1 = 2.10 - c MSR2 = 4.09 - ef MSR3 = 3.11 - lc MSR4 = 4.25 - lf FT = 3.50-lc/ef X = 3.5 - lc	**Making** X = 3.7 - lc/ef	0.20

The first and second columns of the above table-(i) shows the Mean Score from Piaget's reasoning task (pendulum task) and the Stage Cognitive Development Level. The third column shows pupils' mean cognitive Response level (PMCRL) to design technology tasks/questions. The fourth column indicates the Mean Cognitive Level of the activities in the National Curriculum Design Technology at KS3 and KS4. The last column shows the difference between pupils' Mean Cognitive Response Level and Mean Cognitive Level of the activities in the National Curriculum, Design Technology at KS3 & 4.

The degree of appropriateness of the match can be interpreted by a comparison between the pupil's Mean Cognitive Response Level (PMCRL) Column (3) and Mean Cognitive Level of design technology at KS3 & KS4. This difference is listed in column (5) as the difference of the pupils Mean Cognitive Response Level PMCRL, and the Mean Cognitive Level of design technology at KS3 & 4.

The grading and interpretation of the difference was as follows:-

0 - .5	-	at or half a level above Pupils' Cognitive Level
.6 - 1.0	-	a level above the Pupils' Cognitive Level
1.1 - 1.5	-	a level and a half above the Pupils' Cognitive Level
1.6 - 2.0	-	a level two times above the Pupils' Cognitive Level.

Thus, 0 - .5 was regarded as an excellent match: 0.6 - 1.0 was regarded as a good match, 1.1 - 1.5 was regarded as a fair match and 1.6 - 2.0, a poor match.

From the data presented, there was a good and excellent match between pupils' Mean Cognitive Response level and the Mean Cognitive level of design technology in respect of design and making respectively.

Could the difficulties experienced by the pupils be due to a lack of motivation of the pupils or the teaching strategy used by the teachers? This aspect is worth investigating further.

The issue of the relationship between pupils' Cognitive level of development and their responses to design technology work, was examined, particularly with regards to the exploratory questions posed at the beginning of this investigation. (i.e. in Chapter 1.) The next and final section would attempt to answer and discuss some of the implications for these exploratory questions

SECTION -6

CHAPTER 10 ~ DISCUSSIONS

I will begin this section by attempting to answer each of the exploratory questions posed at the beginning of this investigation and then discuss some of the curriculum implications of the results obtained.

10.1 Question 1: Will analysing students' responses provide us with responses that can be categorised into each of the developmental levels and what are the characteristics of those responses at each level?

Analysing the responses of all students in the study provided a developmental sequence of the characteristics of the different cognitive levels. The responses have been organised according to the developmental stages adapted from SOLO Response Taxonomy and elaborated on in the guidelines created by the design and technology taxonomy developed for this thesis. Thus, the superordinate structure reflected the developmental levels or stages described by Piaget. The subordinate levels are organised according to students' responses. The structure for these responses reflected a combination of the SOLO Response Taxonomy and the Design and Technology Taxonomy developed by the investigator. The students, responses are from a written task and discussions of tasks. These data are presented in the following developmental sequence:

10.0.1 PUPILS' RESPONSES TO DESIGN AND TECHNOLOGY TASKS

Pre-Operational Responses

1. Pupils did not respond to the question.
2. Pupils re-stated information from the question.
3. Pupils responded with something irrelevant to the tasks given.

Early Concrete Responses

1. Pupils responded to the question with a single fact relevant to the information provided in the tasks.
2. Pupils, response focused on the specific event or objects in the task.
3. Pupils considered all facts and events in the tasks as having equal importance.
4. Pupils stated simple one-factor causes.

Late Concrete Operational Responses

1. Pupils responded to the question with more than one relevant factor.
2. Pupils responded with facts both relevant to the specific tasks and with facts derived from other sources with their experiences.
3. Pupils recognised contradictions in the tasks but were unable to explain and resolve these.

Early Formal Operational Responses

1. Pupils responded by connecting the relevant facts to overall principles and generalisations.
2. Pupils related the relevant factors to inferential considerations beyond their direct experience.
3. Pupils elaborated and embellished upon the responses.

Late Formal Operational Responses

1. Pupils responded with logical data that extended beyond what was required or given.
2. Pupils responded with answers that related to both the task as a whole and to some inferences to hypothesis important from their own experience.
3. Pupils stated broad general principles beyond the context of the tasks.

Analysing responses in this manner provided a developmental perspective of pupils' responses to design and technology. The Piagetian stage framework provided a sequence, ranging from pre-operational to concrete operation to formal operation. Within the sequence a subject can respond in a variety of ways; the manner in which the subject responded reflected his/her thinking, which corresponded to the characteristic nature of the subject's stage/level of development. Consequently, a pre-operational response consisted of either no response or a response that had no logical relationship with the question. An early concrete operational response contained one relevant detail and was related to the question. A late concrete operational response contained more than one relevant detail and was related to the question or task. Little attempt, however, was made by the subject to relate these details or incorporate them into inferential statements. Contradictions when recognised were left unresolved. The early formal response utilised the specific idea of tasks and began to state logical relationships and generalisations. Subjects, when responding, attempted to resolve contradictions. The late formal responses went beyond the materials presented by the tasks. The subjects responded by stating principles, resolving or posing contradictions, and by making predictions. This system of response analysis was a useful technique for interpreting the subjects understanding of material.

10.2 Question 2: Will pupils respond with correct answers to questions when they are appropriately matched to their cognitive level?

From the data presented on Table (Summary Mean PMCL & MCLDT), the indications were that the relationship between the pupils mean cognitive level and mean cognitive level of response was about 0.6. Chi-square Analysis also yielded values (see appendix-9) which suggested that the level of response and the level of questions were not independent of each other. This finding which indicated that a large majority of the responses were concrete operations was consistent with the scores on the Piaget Pendulum Formal Reasoning. The questions were analysed according to Blooms Taxonomy and related to Piagetian categories and SOLO levels.

Categories (Bloom's)	**Piagetian**	**Solo Levels**
Knowledge	Concrete	2
Comprehension	Concrete	2
Analysis	Late Concrete	3
Application	Early Formal	4
Synthesis	Late Formal	5
Evaluation	Late Formal	5

10.3 Question 3: Can a taxonomy for estimating the level of thinking demanded by design and technology be developed?

A taxonomy for estimating the level of thinking demanded by design and technology was developed. It appeared in the section on taxonomies. A taxonomy was constructed utilising the Piagetian framework and Shayer and Adey taxonomy. The creation of this taxonomy provided a method of estimating the level of thinking demanded by design and technology. It can be used to guide and select appropriate objectives and realistic activities for students. Further, it can assist in predicting how students will perform with design and technology. Therefore, it became an important instrument to be adopted when teaching design and technology simply by :

(a) identifying the schema (e.g. classification) required for design and technology objective(s);

(b) reading the curriculum objectives to see if they require the pupils to analyse or apply according to Bloom's taxonomy of knowledge (or objectives).

(c) using the table above to determine Piagetian level equivalent, e.g. analysis has as its equivalent late concrete operation.

(d) using design and technology taxonomy developed for this thesis to map the range of thinking demanded by the design and technology objective(s). The design and technology curriculum taxonomy describes the range of possible responses or thinking within the subject area demanded of pupils or are able to produce.

10.4 RECAPITULATION

It will be remembered that the principal aim of this exploratory investigation has been to attempt to relate the psychological characteristics of the pupils to the demands of a technological curriculum, partly in the hope that the difficulties pupils have when solving design and technology problems could be explained in psychological terms. In order to achieve this, the investigator attempted to:

(a) establish a technological thinking "style" typical of pupils in secondary schools;

(b) assess the level of demands made on the pupils by technological activity (curriculum), and matching (a) and (b).

Whereas, (a) above has involved describing pupils' actual thinking as they are involved in solving technological problems, (b) has involved analysing curriculum activity (teaching and syllabus materials). It is important to take both of the above steps (a) and (b), are important because the notion of "matching" presupposes that teaching and pupils' conceptual levels be well integrated.

Furthermore, a Design and Technology taxonomy of the different schemata required for understanding design and technology was developed. The schemata identified by Piaget served as a basis for the taxonomy. Eight schemata were identified as important to Design and Technology learning. They were Classification, Seriation, Frame of Reference, Spatial-Temporal Relationship, Causality, Correlational Reasoning, Proportional Reasoning and Formal Logic.

The subjects were selected from three comprehensive schools across the London Boroughs of Ealing and Wandsworth. Each participants was administered Piaget's Test of Formal Reasoning. The investigator also selected major tasks from the National Curriculum on Design and Technology and then analysed them using the Design and Technology Taxonomy. This determined the cognitive schemata necessary for learning design and technology, and the cognitive level of the schemata contained in the task. The investigator prepared written and practical tasks and rated them according to Bloom's Taxonomy and the cognitive level of development.

Thus, the Knowledge and Comprehension questions were constructed/structured so that they exhibit Concrete Operational thinking. Analysis questions, too, were structured to exhibit Late Concrete Operational thinking. The application questions were constructed to exhibit Early Formal Operational thinking, and the synthesis and evaluation questions were constructed to exhibit Late Formal Operational thinking.

Thereafter, the investigator analysed all written and oral responses for their cognitive level, by comparing them to the descriptors indicated in the SOLO taxonomy. The data from the pupils' responses and their performance levels on Piaget's Test of Formal Reasoning were collected, analysed and compared.

As is apparent from this investigation, technological thinking is not a phenomenon that can be determined in advance of time. So that the fact that pupils' technological thinking has been described presupposes that they have actually done some technological tasks and have been observed. This is important because a more accurate description of technological thinking has thus been ensured.

However, in attempting to describe technological thinking, one of the assumptions has been that it will be largely accounted for in terms of Piaget's formal operational thinking. A good Piagetian, if there are any still left, will argue that the most important thing is the formal operational stage, because it seems to embody a wide range of abilities which children can apply to anything: technological problems, scientific problems, historical problems and everyday problems. This would have been the case if, after having administered Piagetian test of formal operation (pendulum test), and carried out a factor analysis, the first identified factor was defined by the pendulum test with all the other tests loaded on this first factor.

Further assumptions centred around the activities thought to be typical of technologists; for example, designing, making things work, manipulation, visualisation etc.

Tasks which, included designing, manipulating systems and dimensions, science thinking, were assembled/designed on the basis of the above assumptions, and the pupils were observed doing these tasks by means of a video camera.

The results from administering these tasks showed that technological thinking involved factors which included 'function/structure', 'general intelligence', and 'perceptual (visual) analysis', 'science reasoning', 'logical/systematic thinking' and 'practical ability'. These were explained in the previous sections and are linked to the different schemata required for understanding design and technology work, identified in the taxonomy; e.g. classification, categorisation.

10.5 CONCLUSION

Analysing students' responses to questions that are cognitively-rated can provide a developmental sequence of characteristics of the different cognitive levels.
Students responded to questions with answers that were matched to their cognitive level of development. The data indicated that about 70% of the responses were Concrete Operational and that about the same percentage of the pupils were at the Concrete Operational level of development when measured by Piaget's Test of Formal Reasoning. Furthermore, pupils responded to questions at their Cognitive Operational level, rather than at the level of the question. They did not utilise abstractions in answering questions unless they were at the Formal Operational level of reasoning.

A taxonomy for estimating the levels of thinking demanded by design and technology can be developed and appears in the Taxonomy section. Briefly, the development of this taxonomy for design and technology required a understanding of and reflection on the work of Piaget in science and other area of the curriculum, which was reviewed in the chapter 2 of this thesis. Furthermore, it also required a very delicate deployment of Bloom's and SOLO taxonomies, and the analysis of the design and technology curriculum at Key Stages 3 and 4 besides, the pupils responses to design and technology tasks.

This investigation is not to be thought of only in terms of empirical/ empiricism, but in terms of a combination of empirical and analytical factors. After all, this investigation sought to bring together the theoretical/ philosophical, the psychological and educational practice. In this respect, Heiddegerian philosophy becomes pertinent, in terms of functional analyses. Technology is part of our being in the world and should be seen in these terms, rather than in terms of 'structural' or abstract analysis. Most educationalists would find this notion difficult to accept. Technology should be about the 'New World', they would say.

In terms of the teaching styles identified here, the teachers themselves may not have grasped this notion. They see technology along the model of science. For example, a 15 year old pupil, starting an electronics course, and being given a test book on electronics, to read, and lectures to attend, represents a model of teaching which sees technology as an academic discipline or science, compared to a whole range of things that the pupil in question can be doing when making circuits etc., etc. Though we still have to go a long way to bringing out the full implications of the broader view of technology, the results from this investigation suggest that teachers ought to be much more into Heiddeger than Piaget.

10.6 SUPPORT FROM OTHER SOURCES

The results from this exploratory investigation find support from a number of sources, notably, psychometrics (structure of intellect) and developmental psychology (individual differences, cognitive style, Piaget).

For instance, psychometrics, which is concerned with quantitative study of individual differences between pupils, has as its basis the idea that the effective way of teaching somebody will depend on what kind of person he is. Thus, a knowledge of the structure of pupils, thinking or intellect is essential. These are however, required to ascertain this.

It will be remembered that Vernon (1950, 1961), including his predecessor, Spearman, arrived at the idea of structure of intellect (group factor), after administering a number of tests, (ten or more), and factor analysing the scores therefrom, to infer the existence of underlying dimensions.

In an attempt to account for what is responsible for the apparent better or worse performance of the pupils in one test than in others, given that the test scores are positively correlated, Spearman comes out with the idea of a general factor "g" (typically identified with intelligence).

In this investigation, as can be seen, a number of tests were administered to pupils, and the scores therefrom were factor analysed to determine the existence of underlying dimensions of technological thinking. Six dimensions have emerged, and were described in the preceding section. There is, however, the possibility that more dimensions can be elicited.

Furthermore, the functional/structural category identified can be regarded as representing pupils' "cognitive style". Similar category has been identified by Kogan (1970) and Witkin et.al (1977). The characteristics of field-dependent/field-independent, namely, stability and bi-polarity, are similar to the first identified factors in this investigation.
The idea of "style" has arisen following reports from studies on convergent and divergent thinking which point to the fact that individuals tend to tackle problems in characteristic ways. In some ways, this is to encourage teachers to focus their interests on the pattern of pupils' learning, and the ways their own patterns of teaching interact with these.

The findings from this investigation also find support from Piaget's developmental work. It was reported here that the pupils appear to think first in "functional" terms, then they go on towards "structural" terms. From Piaget's developmental research, we learn that adults think a bit more in terms of "structures", (as defined here), than "function". The idea of pupils thinking "functionally" is linked to the notion of the development of the intellect through doing things. That is, one develops intellectually, by performing action upon objects.

The description of some of Piaget's basic concepts, for example, "action", "stages", "structure", etc., with which we are all too familiar, exhibits these characteristics.

This investigation was designed utilising a Piagetian framework and correlated with information from the cognitive assessment work descriptive developmental taxonomy of Shayer and Adey, and the SOLO Taxonomy outlined by Biggs and Collins (1982). The investigator concurs with their research findings that not only can pupils' cognitive (technological thinking) levels be ascertained, but that the cognitive levels of curricula can be determined. Furthermore, the response pupils expressed to questions may indicate their cognitive level of development.

10.7 CURRICULUM IMPLICATIONS

Having identified and described the structure and development of design and technological thinking in secondary schools, the implications of some, though not many of the findings from this investigation for Design and Technology Education can be discussed in terms of:

1. the development of the design and technology curriculum: (what should be the basis for design and technology curriculum development/);

2. the teaching of design and technology to pupils.

With respect to the development of the design and technology curriculum, given the results from this investigation, and the instances of what a design and technology curriculum does, it may be that design and technology curriculum planners will have to build on "functional" rather than "structural" responses. In other words, "function" will be one of the factors which ought to guide developers of the technology curriculum.

Whereas it is one thing for the curriculum to emphasise "function", it is another thing for the teachers actually to teach in a manner that expands this functional characteristics, in view of their "structural" disposition.

Since it is apparent that not many teachers of technology subjects know how to describe the skills involved in technological work, this investigation has attempted to identify and describe some of these technological skills. Their development and importance in schools' technology work (class room) have also been shown. If teachers want to develop pupils as technologists, then they ought to be developing the skills identified here.

However, as a result of the teachers being aware of these rather important skills, (which are more or less their pupils' preferred "style" of operating), the assessment of their pupils' progress can be observed and/or monitored. Moreover, they will be encouraged to make their pupils look equal during their teaching sessions. It is also important to remember that an important component of the pupils' understanding of design and technology, is an awareness of the schemata present in Design and Technology and the schemata present in the pupils when selecting design and technology. This knowledge and creating a match with it may be a crucial component to structuring a learning situation where the pupils will comprehend the design and technology. Through the construction of appropriately selected tasks which are then matched to the cognitive level of the students, and to design and technology, some sort of mediation/intervention can take place. This intervention can lead to comprehension beyond the Uni-structural level.

The SOLO Taxonomy and the Design and Technology Taxonomy developed for this study can be applied to analyse pupils' responses and the cognitive levels that are present in design and technology. These techniques provide a rational and systematic process for attempting to mediate the interaction between the demands of the Design and Technology and the pupils own cognitive level. Therefore, in selecting Design and Technology activity, it is necessary to:

1) analyse the cognitive level of the pupils
2) analyse the cognitive level present in the Design and Technology activity activity/test
3) develop questions which enable pupils to respond at levels appropriate to the cognitive levels in the task
4) assess the responses to the pupils
5) mediate or match those so that comprehension occurs.

The essence of response develops a new position in the teaching of design and technology as a result of this investigation. No longer is there a single correct response to a question. All responses become valuable data and are appropriate because they reflect the students' cognitive level of development. Response thus is perceived as more than a mere reproduction. It becomes a vehicle for informal assessment of students' cognitive level and a guide for selecting appropriate design and technology tasks for that student.

In addition, there is the recognition that students' responses will be comprised of a wide range of answers from restatements to generalisations to hypotheses related to the task. The range of responses will be dependent upon the schemata contained in the task and the level of questions/tasks proposed by the teacher.

Finally, when design and technology is discussed in a setting where questions are designed to match all cognitive levels of the students present, and all responses are valued, a positive atmosphere may be created. This atmosphere may foster further development of the students since they may be more involved in the activity under discussion. All students are able to participate in this setting since questions have been structured to meet their levels and all responses are valued.

10.8 KEY MESSAGES FOR DESIGN AND TECHNOLOGY TEACHERS

- The conception of design and technology as a subject for the intellectually less able is misplaced. Design and technology is more than just practical skills.

Indeed, it is known to makes a considerable intellectual demands on children's ability. It is practical intelligence operating within the context of abstraction (science), expression(arts), and belief. Empirically speaking, technological thinking involves factors such as general intelligence, spatial/perceptual (visual) ability, function/structure (style), logical and systematic thinking.

- It is possible to assess pupil's design and technological thinking/functioning levels providing the process areas to be taught have been identified. The taxonomy developed for this investigation outlines a range of skills that enables the teacher to map out the level of functioning of their pupils. It is possible to see when their pupils are making progress with the help of the design and technology taxonomy.
- To design a good design and technology curriculum, a deeper understanding of the ways pupils think is required. The design and technology taxonomy developed for this investigation is intended to foster this understanding by providing a range of skills level in which teachers expect their pupils to fall with respect to the particular design and technology curriculum objective.
- Developmental analyses show that, during the early years pupils tend to repeat action (operation) illogically ie., without being able to explain their action (operation). However, as they progress through the years their action (operation) become increasingly systematic (logical). In otherwords, children's thinking in design and technology tend to proceed from an immediate concrete operational responses (functional) towards 'structural' which is a more comprehensive way of understanding function. Where ever possible teach the functional aspects of design and technology first, then progress towards the 'structural'(i.e. it would be beneficial to begin the teaching design and technology subjects with some activity (action) and then progress to more sophisticated levels.)

10.9 WAY FORWARD

In the drive towards a paradigm for teaching technology subjects, an even better understanding of the process skills involved in technology may result if:

a) some of the important tests identified here can be validated and administered to a very large sample of pupils in the different year groups;

b) it can be arranged for teachers in different schools teaching the same syllabus topics to the same year group to make notes/lists of the aspects of the topics which they value most over a period of six to ten years. Such a list will be categorised to bring out levels of attainment and provide a means for effective assessment for the pupils.

With some success, along this path, the effects of variables such as personality, sex differences, etc., may become known.

10.9.1 RECOMMENDATIONS FOR FUTURE RESEARCH

Several areas for further investigation emerge from this study. The following recommendations for investigation are suggested:

1. Further investigation should be conducted by using a variety of ethnic groups of students.

2. It would be valuable to replicate this study using a kindergarten-through-year- twelve student population. This would provide a comprehensive spectrum of descriptive responses for all cognitive levels of development.

3. This study could be replicated by using a case study approach.

4. Further investigation should be conducted in the development of taxonomies for other curriculum areas Information Technology and Home Economics.

5. It would be valuable to replicate this study with students identified as gifted.

6. It would be valuable to replicate this study with students identified as having IQs lower than 90.

Though these areas are important and bear the hallmarks of replication studies with different groups, their immediate usefulness to the design and technology teachers could still be remote. An immediately valuable study would be an exploratory research of in-service training using the analysis in this study to get a better understanding of design and technology teaching. Granted that some teachers of design and technology are not fully aware of the concepts in design and technology, some form of in-service training experience to enable them refine their conception or understanding of design and technology would be most valuable.

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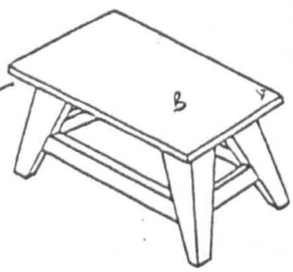
Appendix-1 Design Task D1.2

IN THE PICTURES SHOWN, YOU ARE TO INDICATE WHETHER THE DESIGNS I TO I6 ARE GOOD OR BAD. AND THEN WRITE YOUR REASONS FOR YOUR CHOICE IN THE LARGE BOX ON ANSWER SHEET D-I.2 GIVEN.

They looked at the 'object' and then associated it with the function appropriate [illegible] function it is to perform. The extent to which they relate the object to its appropriate function

L3 x L5
Ave. L4

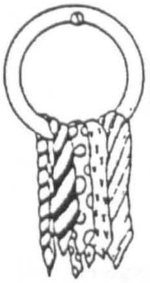
1 *A coffee table*



Bad — Thick legs.

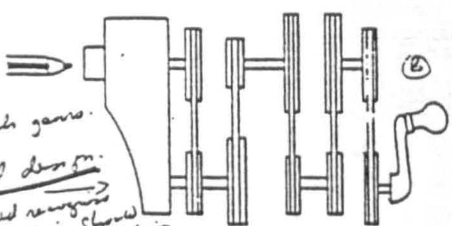
B

2 *A tie rack*



(b)

3 *The inside of a pencil sharpener*



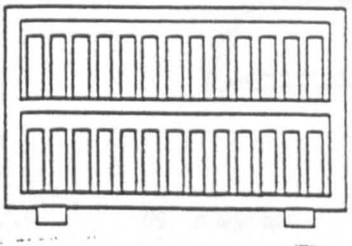
Too much gears.

Bad design.

The should recognise that something should be done about this design — reduce the no. of gears.

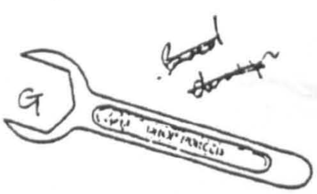
(B)

4 *A cassette rack with cassettes*



G

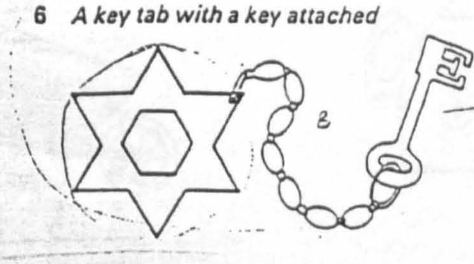
5 *A spanner*



G

~~Good~~ design

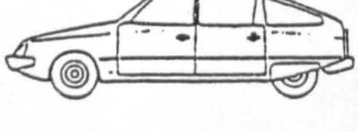
6 *A key tab with a key attached*



B

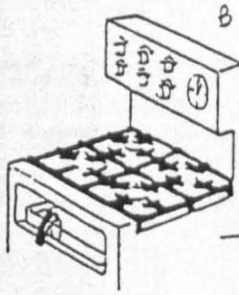
see [illegible] — Confused [illegible] round [illegible] Bad [illegible]

7 *A Citroën CX*



G

8 *Controls on a cooker*

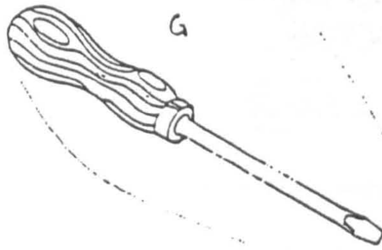


B

They are supposed [illegible] cooker [illegible] space [illegible] between [illegible] and the [illegible]

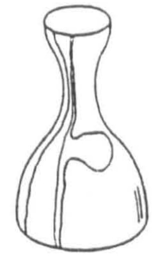
As it is, this is a bad design.

9 *A screwdriver*



G

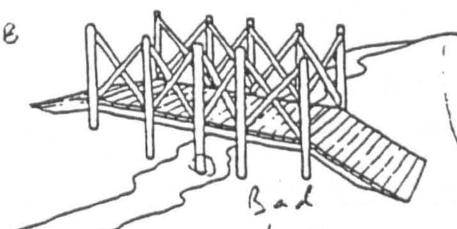
10 *An ice-cream jar*



B

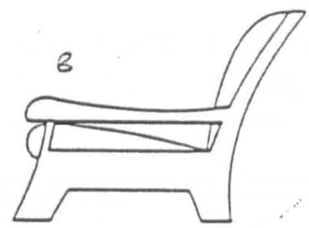
11 *A bridge over a small stream*

B



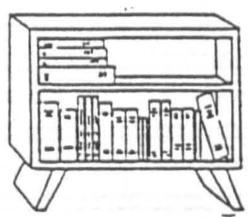
Bad design.

12 *A fireside chair*



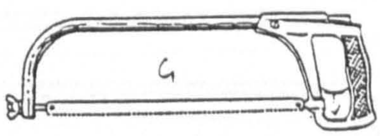
B

13 *A small bookcase*



B

14 *A modern hacksaw*



G

15 *A wheelbarrow*

B

16 *A teapot*

B

R.A.

See Pg 176

ANSWERSHEET D1.2

Teachers Responces to D1.2

This Formed the Basis for Assessing The Pupil's On this Particular Task

INDICATE WHETHER THE DESIGNS ON THE FOLLOWING SHEETS ARE GOOD OR BAD. WRITE YOUR REASONS FOR YOUR CHOICE IN THE LARGE BOX.

Score	No.		Count	Correct Res
G=1, B=0	1	Good / Bad	4G / 3B	G
G=0, B=1	2	Good / Bad	2G / 5B	A
G=0, B=1	3	Good / Bad	7B	B
G=1, B=0	4	Good / Bad	6G / 1B	G
G=1, B=0	5	Good / Bad	4G / 3B	G
G=0, B=1	6	Good / Bad	1G / 6B	B
G=1, B=0	7	Good / Bad	7G	G
G=0, B=1	8	Good / Bad	2G / 5B	B
G=1, B=0	9	Good / Bad	5G / 2B	G
G=0, B=1	10	Good / Bad	1G / 6B	B
G=0, B=1	11	Good / Bad	1G / 6B	B
G=0, B=1	12	Good / Bad	3G / 4B	B
G=0, B=1	13	Good / Bad	2G / 5B	E
G=1, B=0	14	Good / Bad	7G / 0	G
G=0, B=1	15	Good / Bad	1G / 6B	B
G=0, B=1	16	Good / Bad	7B	B

Appendix-2 ' Task D1.3 Aerial Photography and Pupils' Responses.

Answersheet D·1·3

TASK D 1·3

Print your name, class, age, and sex.

Name.----------------------- Age.-----years, -------months

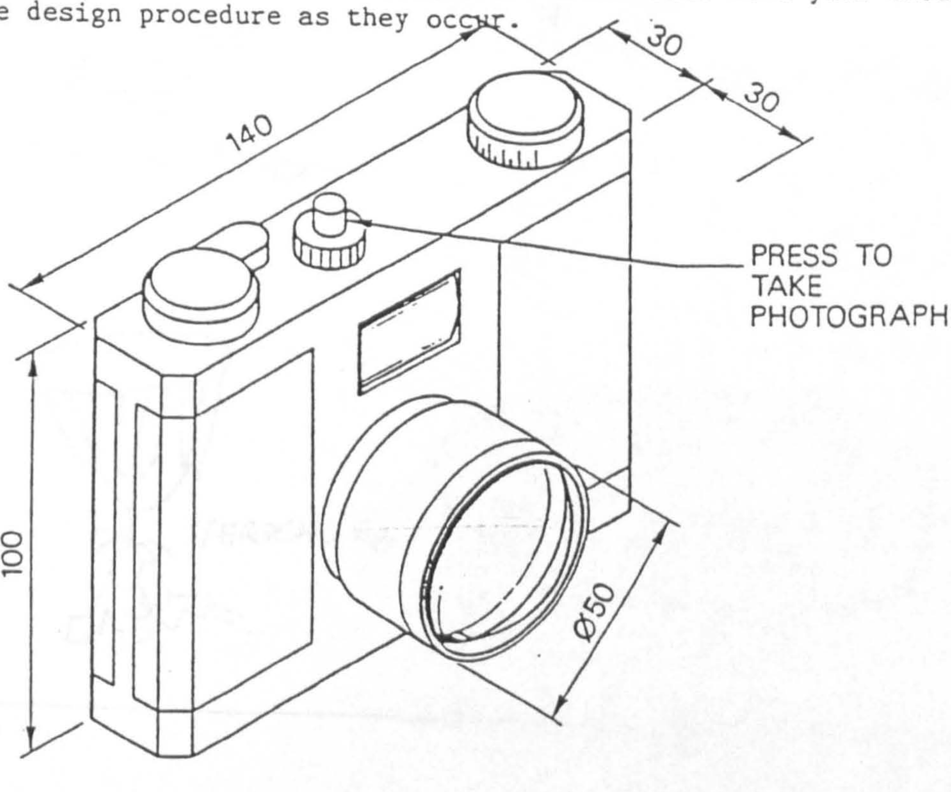
Class.---------------------- Sex. ----- male

----- female

Your school's Geography Department requires an aerial photograph of your school for their map reading course.

Design a device that will carry the camera shown below to a height of at least 25 metres above your school to take a photograph.

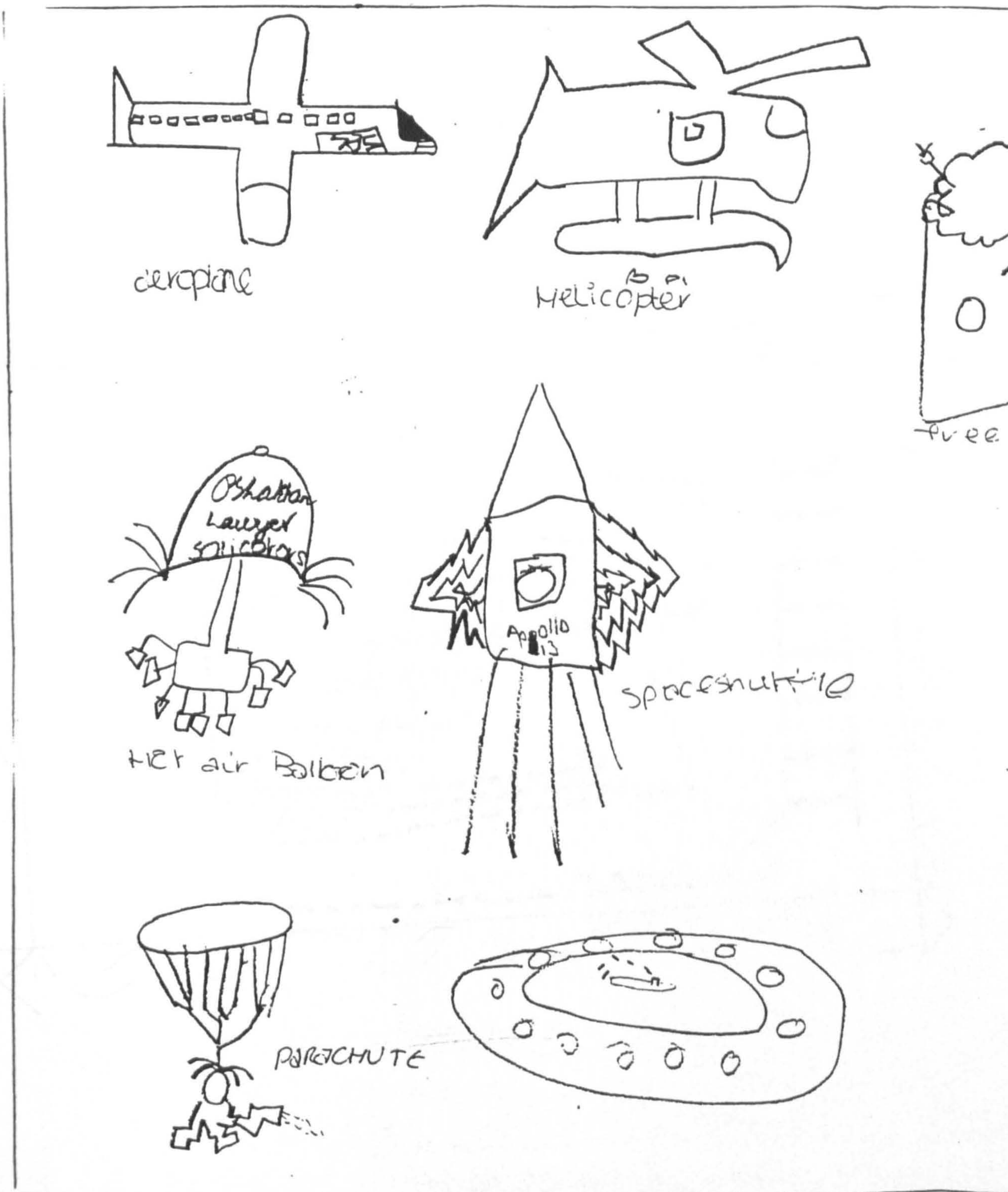
Make a brief note on its construction: then write down your thoughts on the design procedure as they occur.

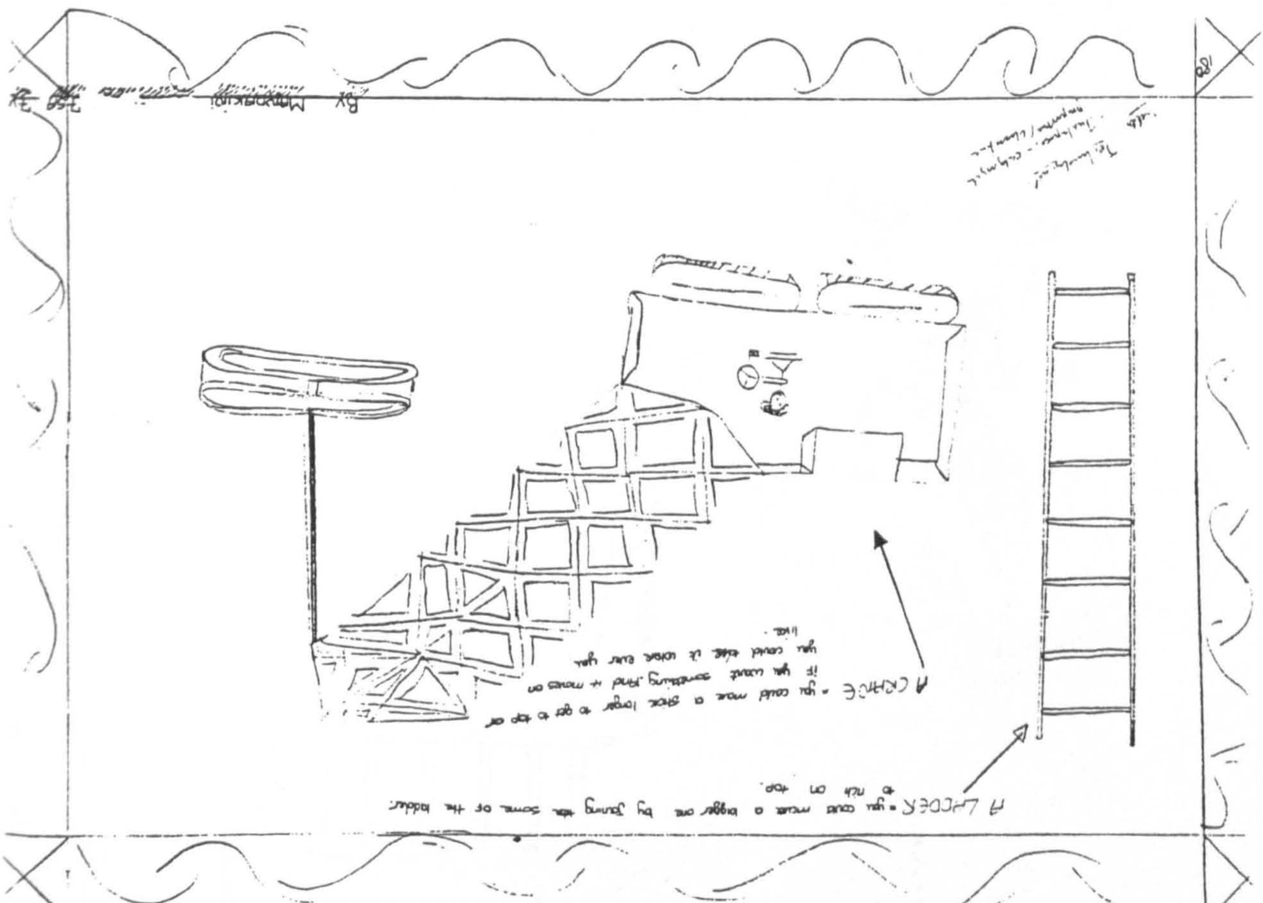


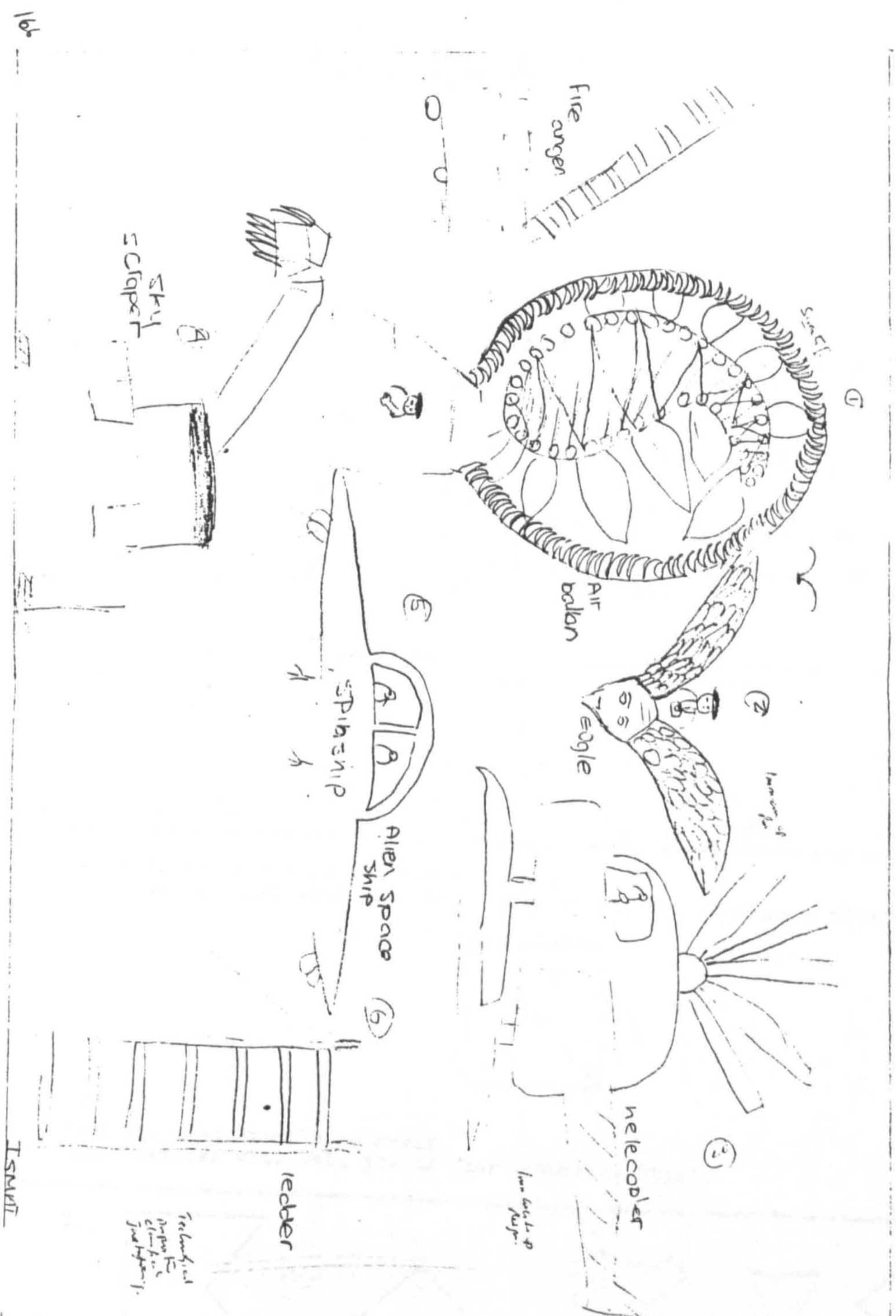
TASK D 1·3

WEIGHT 500 g.

PAGE MISSING IN ORIGINAL


aeroplane
Helicopter
tree
Lawyer
Apollo 13
spaceshuttle
Hot air Balloon
PARACHUTE


A LADDER = you could make a bigger one by joining the some of the ladder. to rich on top.
A CRANE = you could make a stick longer to get to top or if you want something. And it moves on you could take it where ever you like.


fire angen
sky scraper
Air ballon
eagle
spaceship
Alien space ship
helecopter
ledder

Appendix-3 Manipulation Task MSR 1.1 Thinking about Shapes

Analysis/ Synthesis EF/LC

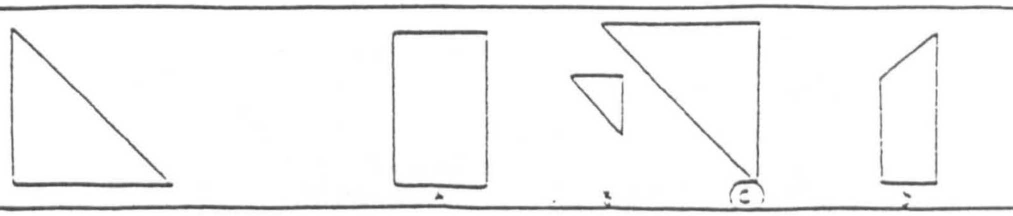
$\bar{x} = 2.7$

SECTION 2 — LC2

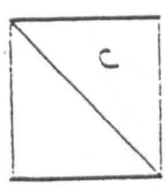
$G \cdot \bar{x} = 3 \cdot$ Lc

In this section, all the items have 5 shapes.
The first shape in each row is a square with a piece missing.
From the other 4 shapes in the row, A. B. C. or D.
choose the one which will fit into the first to form a square.
Circle the letter by the shape you have chosen.

For example:

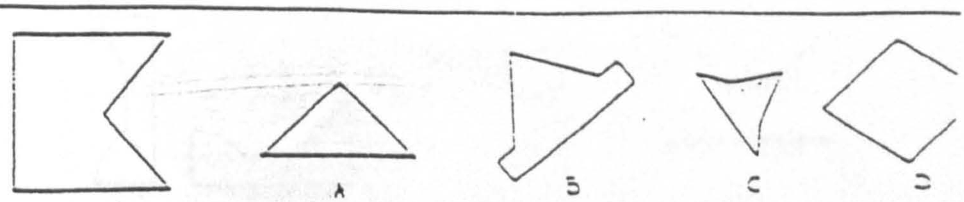


In this example C is the correct answer.
It fits together with the first shape in the row to make a square.



Try the next example yourself.
Your teacher will tell you if your answer is right.

1.

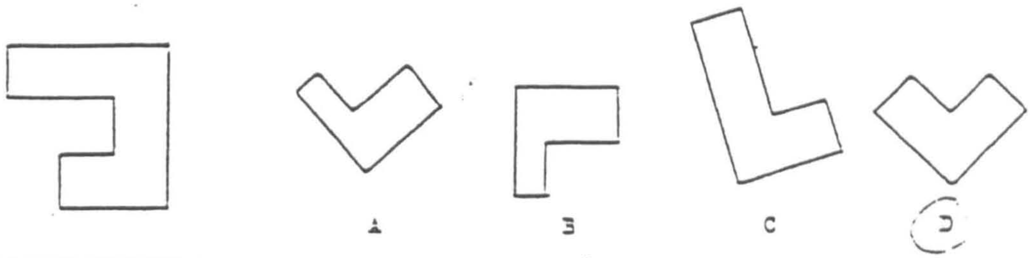


Don't turn over until your teacher tells you to do so.

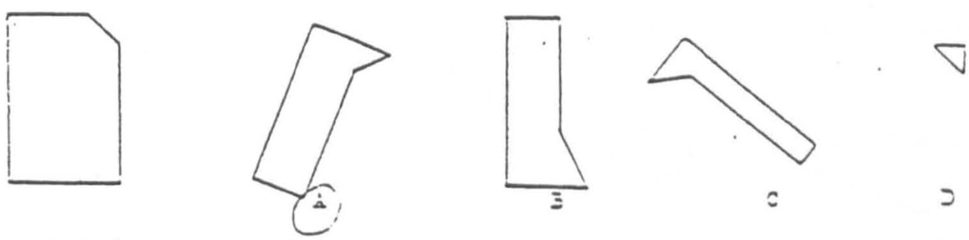
Do the questions on the next two pages then STOP.

Put a circle round the letter by the shape that completes the square.

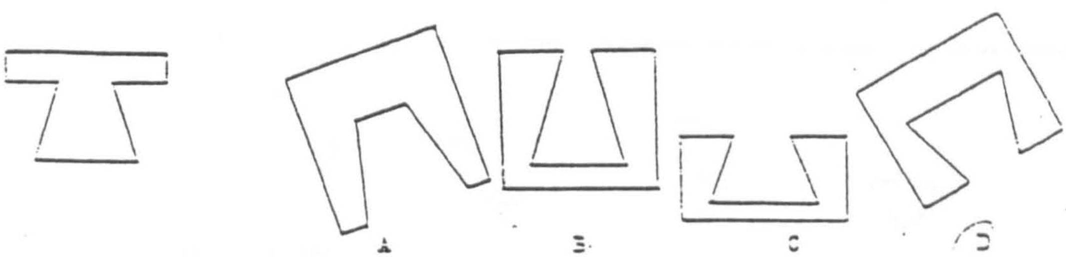
9



10

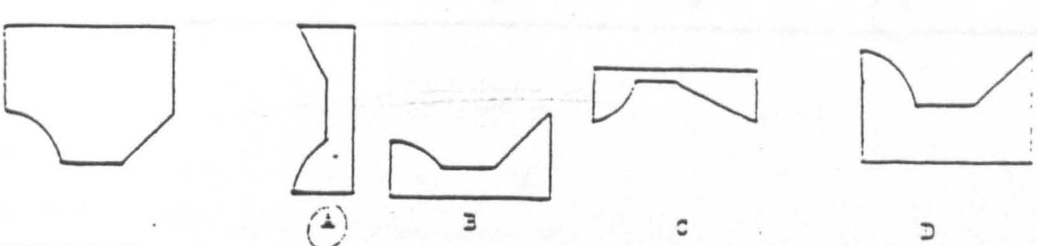


11

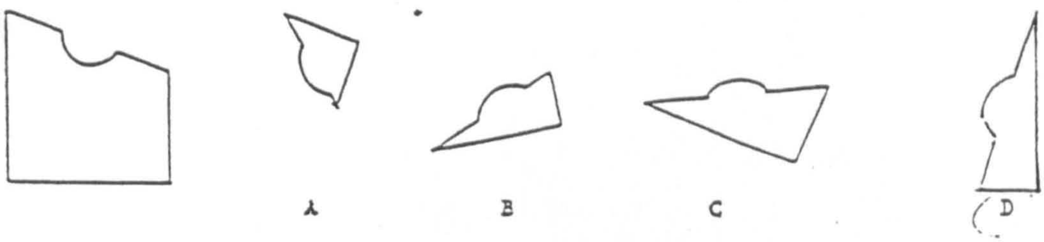


12

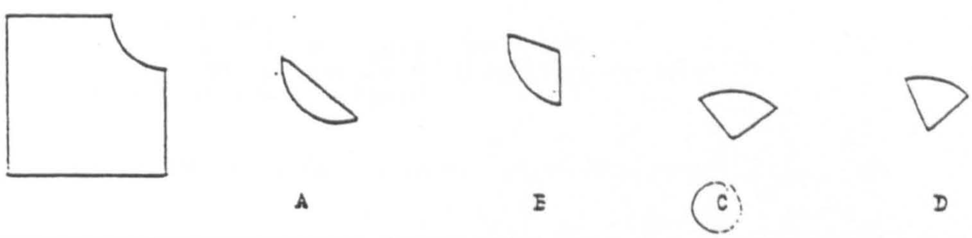
13



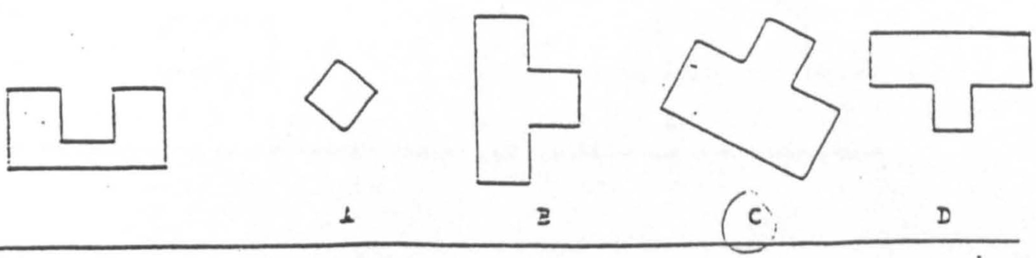
14.



15.



16.

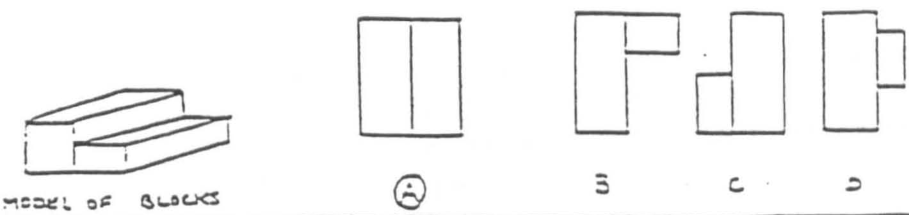


SECTION 3

LC3 $\bar{x} = 4 \cdot 09$.

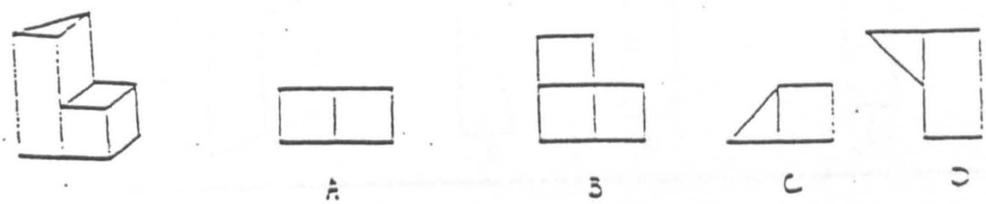
In this section, each question has a picture of a model made with building blocks.
This is followed by 4 drawings.
One of these drawings shows the shape of the model looking down on it from above.
Draw a circle round the letter by the drawing which is correct.

Here is an example



The model is made of two long blocks lying side by side.
When it is looked at from above, it looks like drawing A - so letter A has been circled.

Try the next example yourself.
Your teacher will tell you if your answer is right.
Just put a circle round the letter by the drawing which shows what the model would look like from above.



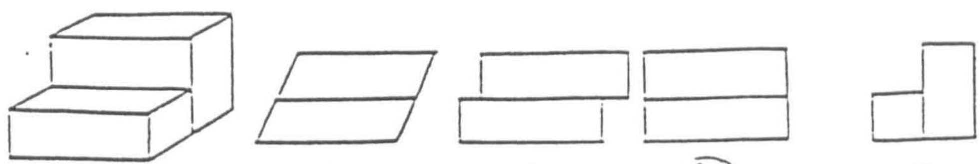
Don't turn over until your teacher tells you to do so.

Do the questions on the next two pages then STOP.

Find the drawing which shows what the model would look like if you looked down on it from above.

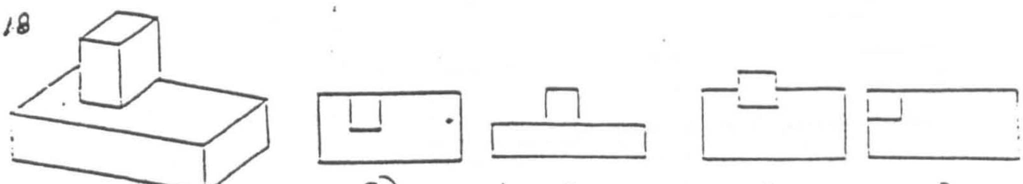
Put a circle round the letter beside it.

17



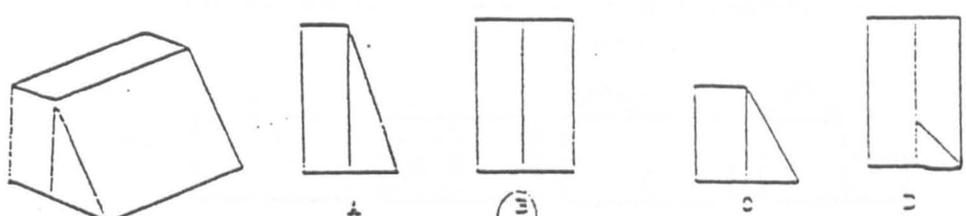
A B C D

18



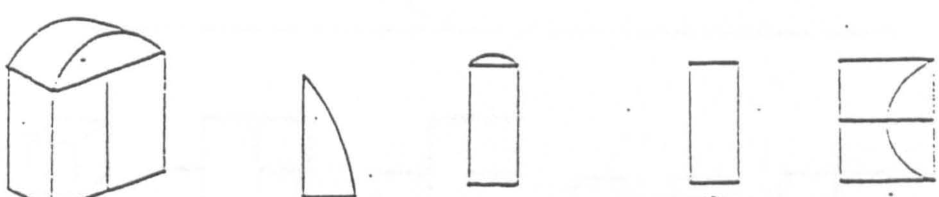
A B C D

19.



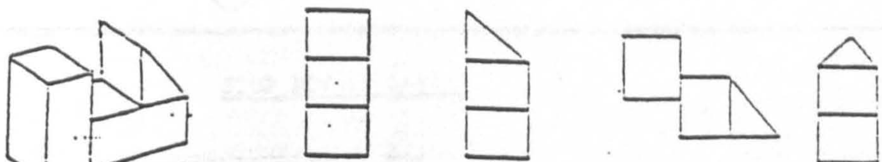
A B C D

20



A B C D

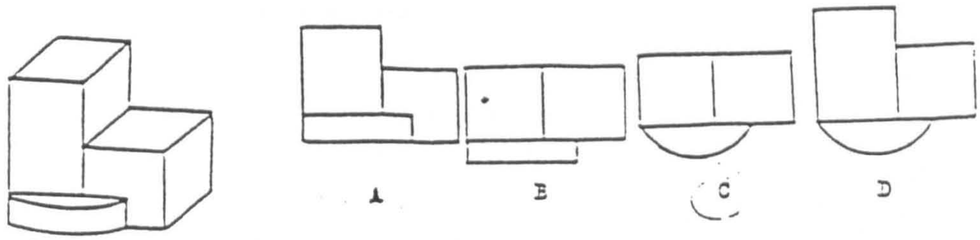
21



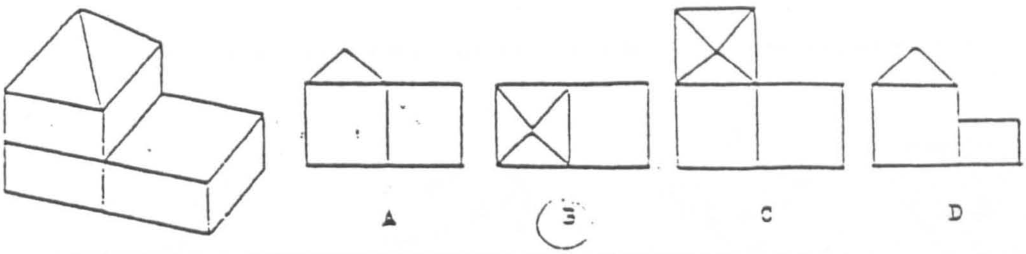
A B C D

9

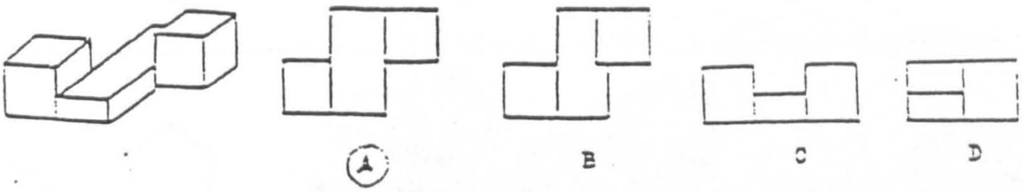
22



23.



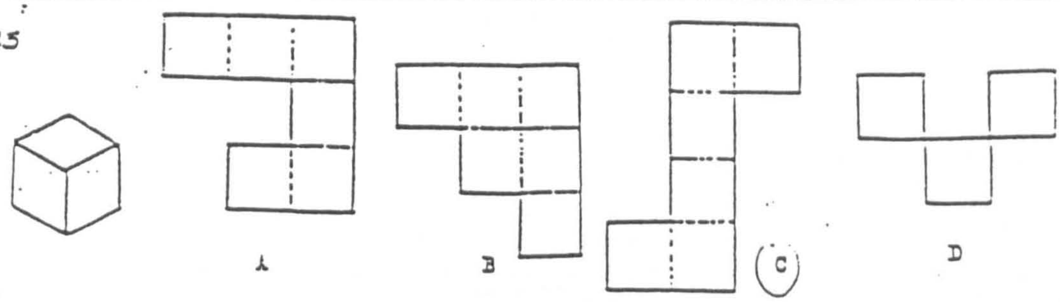
24



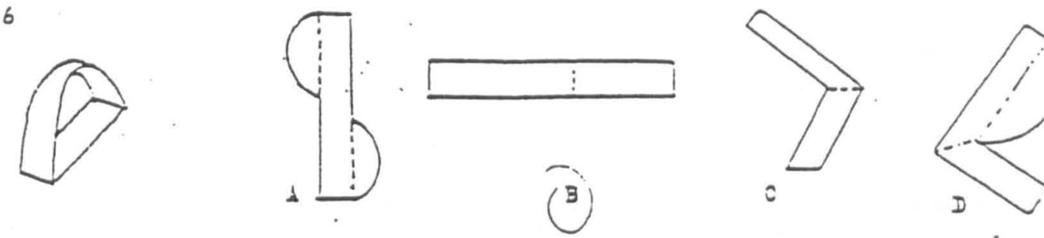
STOP NOW !!!!!!!!!

Find the cut-out shape which would make the model if it was
folded on the dotted lines.
Put a circle round the letter beside it.
Do the questions on the next three pages then STOP.

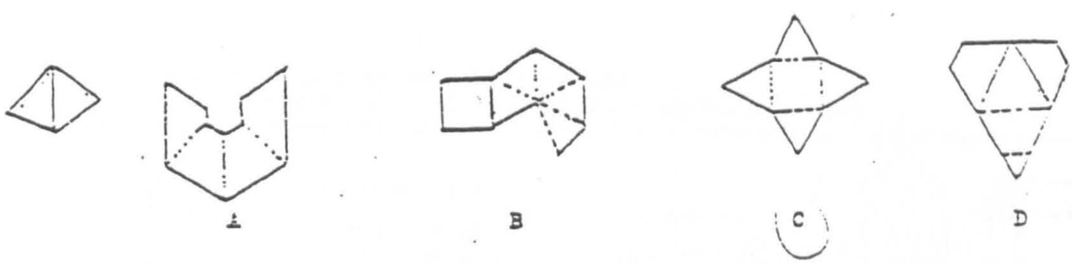
25



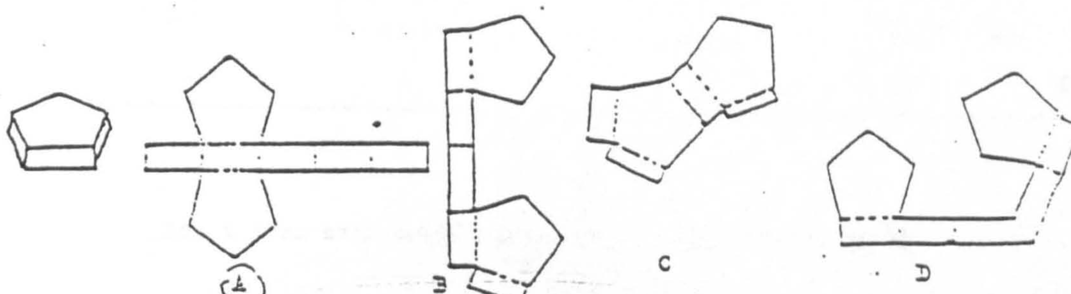
26



27

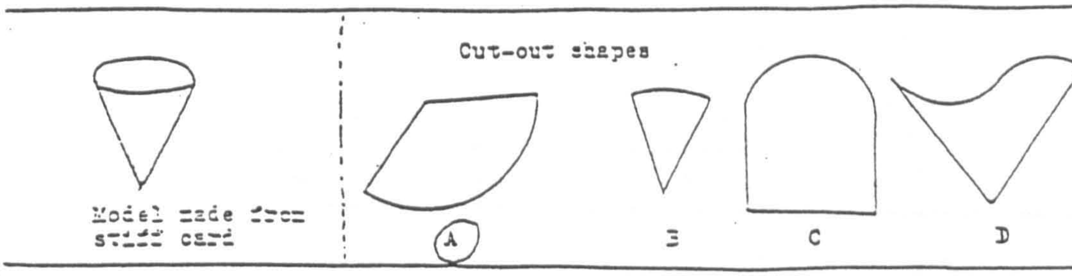


28.



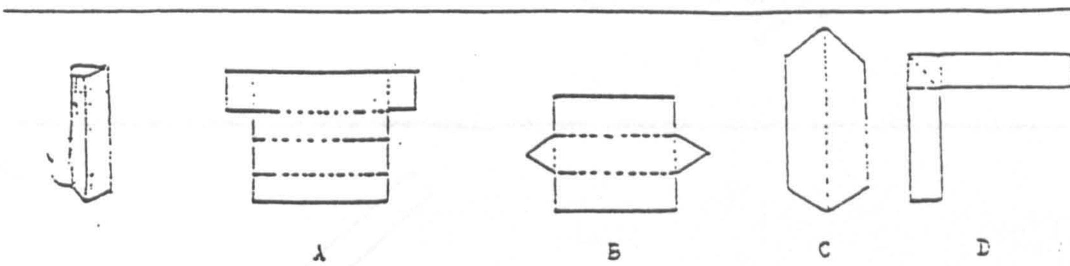
SECTION 4 LF5 3·11

In this section each question has a picture of a model made by folding a stiff card cut-out-shape.
Besides the picture of the model are 4 drawings of cut out shapes.
Choose the shape which when folded would make the model shown in the picture.
Circle the letter under the cut-out shape you choose.



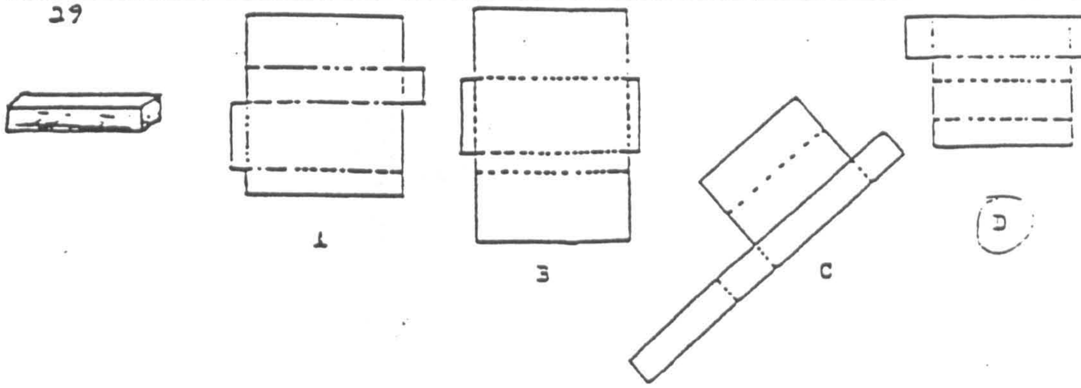
Cut-out shape A, when folded so that the straight edges are together, would form the cone-shaped model in the first picture, so a circle has been put round the letter A

Now try the next example yourself.
Your teacher will tell you if your answer is right.

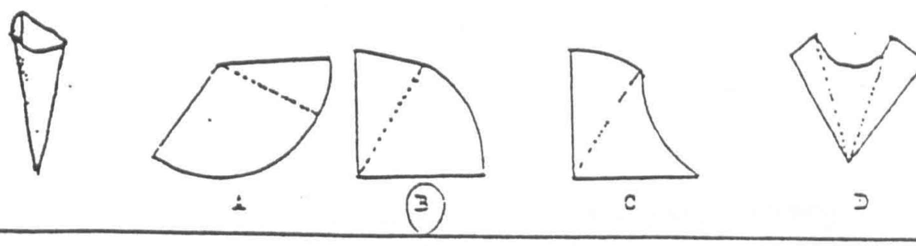


Don't turn over until your teacher tells you to do so.

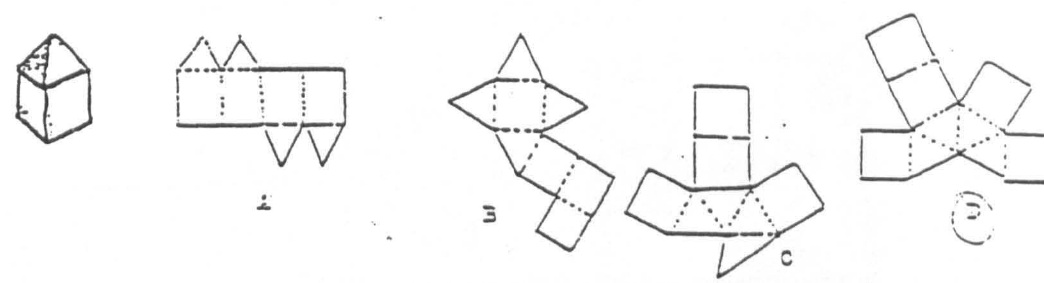
29



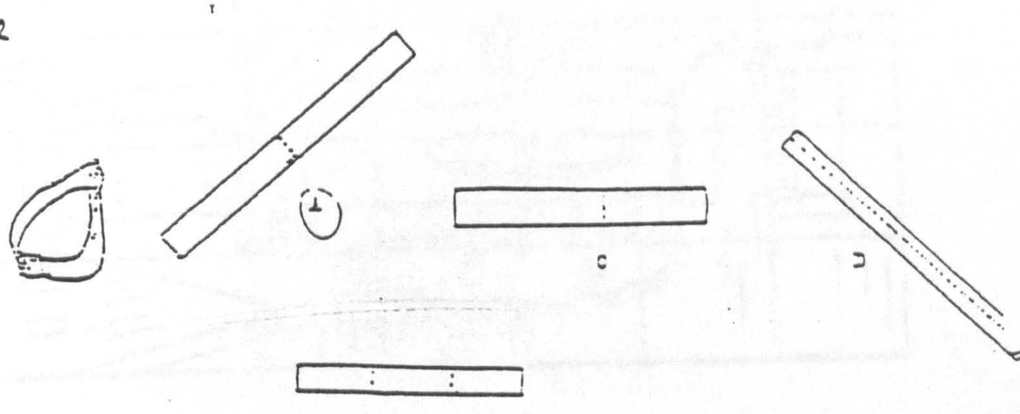
30



31



32



SECTION 5

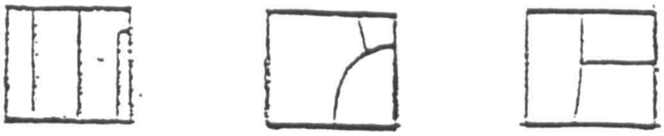
CAN YOU FIND THE BOXES?

The boxes A, B, C, D, E, P and G are somewhere in this large picture.

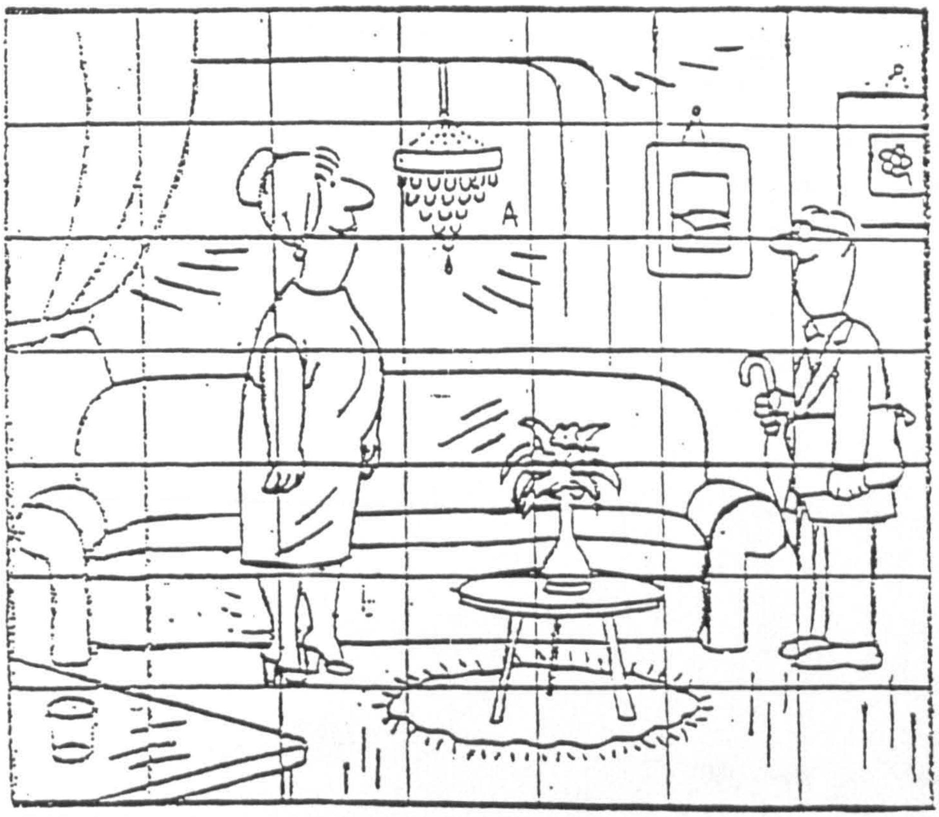
When you find them put the letter by the box in the square on the big picture.

We've done the first one for you.

A B C D



E P G



Appendix-4 Science Thinking Test (Piaget's Pendulum Task)

SCIENCE REASONING TASKS

NAME .... TODAY'S DATE ....

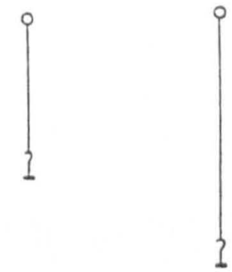
BOY OR GIRL .... CLASS ....

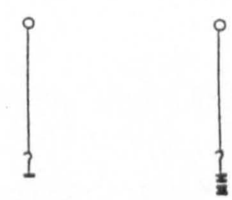
SCHOOL .... DATE OF BIRTH ....
day month year

THE PENDULUM

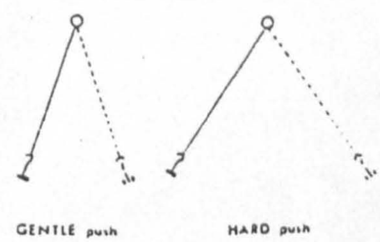
We are going to make a pendulum, using a SHORT or LONG string,
and a LIGHT or HEAVY weight,
and we will exert a GENTLE or HARD push.

SHORT string LONG string





LIGHT weight HEAVY weight



GENTLE push or (narrow swing) HARD push or (wide swing)

length	weight	push	number of swings in ½-minute

A.1 SHORT string, HEAVY weight, GENTLE push.

Your guess:__________swings. Experiment 1 ——————

A.2 LONG string, LIGHT weight, GENTLE push.

Your guess:__________swings. Experiment 2 ——————

A.3 What effect do you think LENGTH, WEIGHT, and PUSH have on the number of swings in half a minute?

LENGTH:

WEIGHT:

PUSH:

A.4a Now what can we tell, if anything, just from these experiments, about the effect of LENGTH, WEIGHT and PUSH on the number of swings?

LENGTH:

A.4b WEIGHT:

PUSH:

A.4c Write down one more experiment that you think would be worth trying next, and explain why you have chosen it. Also explain how this new experient ties in with experiment 1 or 2:

		length	weight	push	number of swings in ½-minute
B.1	Experiment 1	SHORT	HEAVY	GENTLE	
B.2	Experiment 2	LONG	LIGHT	GENTLE	
B.3	LONG string, HEAVY weight, HARD push. your guess:________swings. Experiment 3				
B.4	SHORT string, LIGHT weight, GENTLE push. your guess:________swings. Experiment 4				

B.5 Now write down what these four experiments alone tell us about the effect of LENGTH, WEIGHT and PUSH on the number of swings,

and, for each factor, note down only those experiments that you need to use:

a. LENGTH: b. experiments

c. WEIGHT: d. experiments

e. PUSH: f. experiments

g. Is the evidence weaker for deciding about one of the factors than it is for the others?________________

If so, say which factor:________________

and

EITHER show that the evidence is still sufficient, OR explain why it is insufficient.

		length	weight	push	
A.5	Imagine that we start again with experiment 1	SHORT	HEAVY	GENTLE	
	Which other arrangements would you use to test the effect that LENGTH has on the number of swings?				
	(But please use as few arrangements as possible; put a star (*) next to any arrangements that you don't really need.)				
A.6	Again starting with experiment 1 how would you test for the effect that WEIGHT has?	SHORT	HEAVY	GENTLE	
	(But, again, use as few arrangements as possible; put a star (*) next to any arrangements that you don't really need.)				
A.7	Imagine someone tried these two arrangements (with another pendulum)	long.	heavy	hard	15
		short	heavy	gentle	20
a.	What do they tell us about the effect of the PUSH?				
b.	If there are any other arrangements that you think you would really need to be sure of the effect of the push, write them down (and cross-out any of the original two arrangements that you don't need).				

Science Reasoning Tasks

TASK III

THE PENDULUM

Dietmar Küchemann
Research Fellow, Chelsea College
University of London

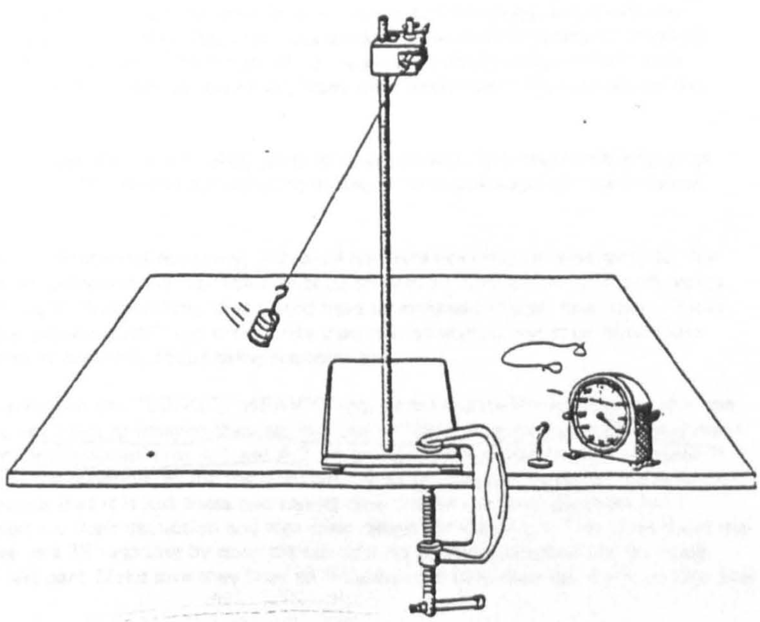
Introduction

This Task* is one of a series developed by the team 'Concepts in Secondary Maths & Science' at Chelsea College, University of London in the period 1973/78 in order to investigate the relationship between the optimum Piagetian level at which a pupil can function and the understanding of Science which he or she can achieve.

This Task investigates the pupils' ability to sort out the effects of three variables; how the Length, Weight, and Push of a pendulum determine the period of oscillation. Of course only the length is important, but the student has to overcome strong intuitive feelings in order to realise this. The Task is based on chapter 4 of Inhelder and Piaget's "The Growth of Logical Thinking," Routledge, London, 1958.
Allow about 45 minutes to complete the Task.

Equipment

Stopclock or watch with second-hand
2 weights (say 100 and 400 gram slotted weights on hangers)
2 strings looped at either end. (Loop to loop distances of 69 cm and 35 cm will give about 17 and 22 swings in half a minute. The numbers are not critical, but try to avoid lengths giving either 15 or 20 swings.)
Firm support to hang pendulum from.



* For information on the use, development, statistics etc. of this Task see the *General Guide*.

Administration

There are not many questions in this Task, so your skill as a teacher snouid be used for creating a comparatively relaxed and slow-moving situation in which your pupils get the maximum opportunity to reflect on the questions which are asked. At any stage feel free to re-phrase any question in any way, so that the problem for the pupils is the one on the page, and not that of understanding wnat the question is about. Here we are trying to maximise the possibility of finding the same range of responses which one might obtain by individual interview.

A.1 Introduce the Task as a series of experiments to find out what factors determine how fast a pendulum swings. Talk through the first page showing them the combinations, with your apparatus, which are given on the cover of their response-sheets. "Gentle" and "Hard" may seem loose to you as a trained scientist but they do not worry the pupils. Occasionally at the end of the Task a few students complain that the push was not standardised, but there is no evidence to indicate that their performances were affected. Make sure they understand that 'how fast' means "How many swings in a given time" and not the velocity of the weights while swinging. Ask them to turn over, and write in the first combination of variables in the columns in the box opposite A.1, and to make a wild guess about the number of swings. Perform the experiment by starting the weight at the bottom, and swinging it very gently out (keep a slight tension on the string so that it doesn't 'bounce'). Time whole swings, "Zero", "One", "Two", etc., and stop the pendulum after ½ a minute. Round off the number of swings to a whole number. Ask pupils to record the result.

A.2 Ask them to write in the new combination of variables in the box opposite A.2, tell them that their guess is again a 'free' one, and is just there to help them think, and perform as in A.1. Again, ask the pupils to record the result.

A.3 Ask for their ideas about how the three variables affect the number of swings. We want answers of the form: "If its longer then . . . . "

- The first three questions (A.1, A.2 and A.3) are not assessed but are designed to help focus the pupils' attention on the problem.

A.4 It is hoped that by asking for their ideas in question A.3 some pupils will then distinguish between their ideas and the evidence in A.4. They will probably think that the two questions are the same, so point out that "here we are interested in what, if anything, this particular couple of experiments show". If they feel they have already answered this question, then of course they can write "see above". The "if anything" is a hint to the intelligent child who might be worried that he must deduce something from every experiment. Do not labour the point.

A.4 Make sure they realise that there are THREE parts to their answers. 1) a new combination of Length, Weight and Push, 2) a reason for choosing it, and 3) an explanation of how it ties in with the first two.

A.5 & 6 This page tests their experimental economy, (a typical concrete operational strategy is to 'try everything') and their awareness that variables must be controlled. Explain in your own words that here we are trying to find out how they would have investigated this on their own. "How would they plan the experiments?" Let them write their combinations, and then draw their attention to the note in brackets, about being economical.

A.7 Say that for this pendulum the "LONG", "HEAVY" etc. weren't quite the same as for the one you demonstrated, ask them to imagine they are looking critically at someone else's experiment so they can't compare the values with A.1 and A.2. In this question we get the 3A response from the last part of the question, so for the question "What do they tell us about the effect of the PUSH?" emphasise that it is just these two results they should use, and ask them for a fairly explicit answer i.e. their deduction and also their reason for making it. This gives them the opportunity to give us a 3B response by pointing out that no proper deduction can be made. Read through the last part. Make sure they have all finished, and only then ask them to turn over to the last side.

Section B, page four is the most crucial part of the Task. Two more combinations of variables are demonstrated, and then B.5 tests their ability to analyse the data reflectively. Here is where most of the evidence is gained as to whether a pupil is using late Formal Operational thinking.

Note that the 4 combinations set up in Section B control the variables so as to allow for unambiguous deductions about the effect of LENGTH (Exp. 2 and Exp. 4), and WEIGHT (Exp. 1 and Exp. 4), but appear not to control the other variables in respect of PUSH. In fact, once the effect of WEIGHT has been deduced, then Exp. 2 and Exp. 3 can be used to deduce the (non) effect of PUSH, and the pupil is given a chance to show this, either in B.5e or in B.5g. It is difficult to spot that the evidence is still sufficient for PUSH, so in B.5g a 3B assessment can be reached by the alternative strategy of explaining that, for PUSH, the other variables were not controlled.

It is important that the data is as clear as possible. Ask them to write in the values from A.1 and A.2, to fill in the details for B.3, and to have a guess about the number of swings. Remind them that their guesses are not assessed, but are designed to help them in their thinking: if their guess is close to the experimental result then their thoughts are probably on the right track, but if not, then they know that they have to think again. Demonstrate B.3 and ENSURE that the answer is the same as B.2, ask them to record. For the Hard push, swing the pendulum about 30° from the vertical. Repeat the above for B.4 and this time make sure the answer is the same as B.1.

Explain in your own words that using just these four experiments we want them to deduce the effect, and direction of each factor. e.g. "if you think they show that weight has an effect, then don't just write 'it has an effect' but say 'if the weight is heavier then you get fewer/more swings in half a minute' ". Explain also that different combinations of the four experiments may be necessary for their various conclusions. Ask them to write in the box labelled "experiments" only those (from B.1 – B.4) they really need in order to make their deductions.

B.5g In your own words point out that "maybe you found one of the factors rather more difficult to determine than the other two. If so, say which (and if not, that's O.K.), and then you've a choice of answers. EITHER show how you used the evidence to make your deduction, OR explain why you think the data is insufficient".

Assessment

Score each result as "1" for adequate, and "0" for inadequate and record on the class assessment sheet. Treat each answer only for the information it gives at the level specified for the question (see Summary of Answers and top of Assessment Sheet). Thus if it is a "3B" question as in B.5g ignore ingenious replies at the 2B level. Similarly a higher level response to a "2B" question still only gains credit at the 2B level.

Summary of Answers

Although these notes on assessment cannot be exhaustive, try and follow them as closely as possible: remember however, that we do not want you to be just a scoring-machine, but rather to maximise your understanding of how your pupils think.

A.1, A.2 & A.3	Do not assess.	
A.4a LENGTH	Score "1" either for "Can't tell because you haven't controlled variables" (a 3B response) or "Longer string; less swings" (a 2B response). Score "0" for "Length has a large effect". Use A.3 answer if in doubt.	(2B)
A.4b WEIGHT & PUSH	Score "1" only for a 3B response; an argued refusal to deduce anything positive. For example "You can't tell because you've varied everything at once".	(3B)
A.4c	Score only for a 3A level of response, that is, a new experiment which explicitly combined with A.1, or A.2 would enable the effect of one named variable to be decided. For example "Long, Light, Hard with A.2 tells you about PUSH".	(3A)

A.5	Score "0" for a whole list of experiments. Score "1" if they have given you LONG, HEAVY, GENTLE, and starred the others (if any). Score "1" if they have given one more correct pair (like SHORT, LIGHT, GENTLE and LONG, LIGHT, GENTLE), but they must be correctly ordered. (do not allow SHG, LHH, LHG, SHH), or, just such a pair with the original experiment starred.	(3A)
A.6	As in A.5, score "0" for a whole list of experiments. Score "1" if they have given you SHORT, LIGHT, GENTLE, and/or one other pair.	(3B)
A.7a Effect of Push	Score "1" for "Nothing, because you've varied length," etc. Score "0" if they have concluded anything positive about PUSH.	(3B)
A.7b Other arrangements	Score "1" for LONG, HEAVY, GENTLE or SHORT, HEAVY, HARD, or both, or another sensible pair, but ignore a long list.	(3A)
B.3 & B.4	Do not assess their guesses.	
B.5a, b LENGTH	Score "1" in 2B column if they've given the effect of length right i.e. "The longer the string the slower the swing" and only then	(2B)
	score "1" in 3B column for "B.2 + B.4" ONLY. Do not give the 3B rating without the effect correct.	(3B)
B.5c, d WEIGHT	Score "1" in 3A column for correct deduction that weight has no effect and only then	(3A)
	score "1" in 3B column for "B.1 & B.4" ONLY. Do not give the 3B rating without the effect correct.	(3B)
B.5e, f, g PUSH	Score both these questions for one 3A and one 3B response. There are two acceptable strategies: either a deduction that push has no effect, or a realisation that since the variables have not been controlled it is difficult to draw any conclusions.	(3A,3B)
	So, score "1" in 3A column for deduction that push has no effect, then score "1" in 3B column if they have chosen B.1 and B.4, followed by B.2 and B.3 for the experiments. They can also gain a 3B rating by arguing in B.5e or g that since they've eliminated weight as a variable, then by comparing B.2 and B.3 they can see that push has no effect.	
	Alternatively, score "1" in 3A column if they have said "You cannot tell about push", but only if this is supported by an answer to at least the 3A level in B.5g e.g. "You need two experiments like L,H,G and L,H,H". This reply is no higher than that necessary for the 3A question A.7. To score "1" in the 3B column they must argue that no deduction is possible since the variables have not been adequately controlled.	

Scoring Rules

(Read from the top; go down this list until you find a combination which fits the pupil)

THREE or more 3B items right	3B
FOUR or more 3A or 3B items right, with TWO effects right [Remember that the effect of LENGTH (B.5a) is a 2B item and cannot be counted in the FOUR higher items, but the effects of WEIGHT (B.5c) and PUSH (B.5e or g) can]	3A
FOUR or more 3A or 3B items right, but without TWO effects.	2B/3A
THREE 3A or 3B items right	2B/3A
TWO 3A or 3B items right plus B.5a LENGTH (2B)	2B/3A
ONE 3A or 3B item right plus A.4a	2B
B.5a LENGTH (2B) right	2B
TWO or less right, without A.4a	2B–

Note that these rules only formalise a 2/3 success principle: If the pupils can give responses characteristic of a stage in 2 out of every 3 possible occasions, then we assume that this, at least, is their capacity most of the time.

FAULT TRACING TASK RECORD SHEET

	F 11.53 60	M 3.23 33	M 3.40 15				
B3-4 = 6	A16 A17 A18	A3 A9	A6				
B2-4 = 5	A14 A15 A20 A19	A5 A11	L2				
B2-3 = 4	A13 A21	A2 A8 A14	A4 A10				
B1-4 = 3	A12 A7 A6 A3	A9 A10	A5 A2 A3 A1				
B1-3 = 2	A11 A8 A5 A1	A6 A12	A8 A9				
B1-2 = 1	A10 A1 A4 A2	A1 A7 A13					
A	A1 A2 A3 A4	A1 A2 A3 A4	A1 A2 A3 A4	A1 A2 A3 A4	A1 A2 A3 A4	A1 A2 A3 A4	A1 A2 A3 A4
B1-2 = 1							
B1-3 = 2							
B1-4 = 3							
B2-3 = 4							
B2-4 = 5							
B3-4 = 6							

Yr 3

Appendix-6

TABLE 4

MEAN AND STANDARD DEVIATION - YR 7

Number of valid observations (listwise) = 55.00

Variable	Mean	Std Dev	Skewness	S.E. Skew	Minimum	Maximum	Valid N
ACCON	1.64	1.58	.05	.32	.00	4.00	55
ACDIV	2.20	1.74	-.21	.32	.00	4.00	55
ACT	3.84	3.17	-.10	.32	.00	8.00	55
BOY	.60	.49	-.42	.32	.00	1.00	55
D1.2	8.80	2.73	.13	.32	3.00	15.00	55
D1.3	.55	.50	-.19	.32	.00	1.00	55
D1.3LLC	.45	.50	.19	.32	.00	1.00	55
D1.3MS	.31	.47	.85	.32	.00	1.00	55
D1.3USF	.64	.49	-.58	.32	.00	1.00	55
FT	.40	.49	.42	.32	.00	1.00	55
GIRL	.40	.49	.42	.32	.00	1.00	55
MSR1	1.82	1.38	.52	.32	.00	5.00	55
MSR2	3.65	2.30	.35	.32	.00	8.00	55
MSR3	2.60	1.58	.06	.32	.00	6.00	55
MSR4	3.51	2.05	-.39	.32	.00	6.00	55
MSRT	11.49	6.02	.07	.32	.00	24.00	55
PSL	2.24	.64	-1.13	.32	.00	3.00	55
SCIREA	1.73	.99	-.84	.32	.00	3.00	55
TCON	2.13	2.02	.11	.32	.00	6.00	55
TDCT	5.51	4.46	-.14	.32	.00	12.00	55
TDIV	3.44	2.81	.07	.32	.00	8.00	55
TFT	1.13	1.26	.78	.32	.00	4.00	55

TABLE 5

HISTOGRAM MEAN RESPONSES YEAR 7

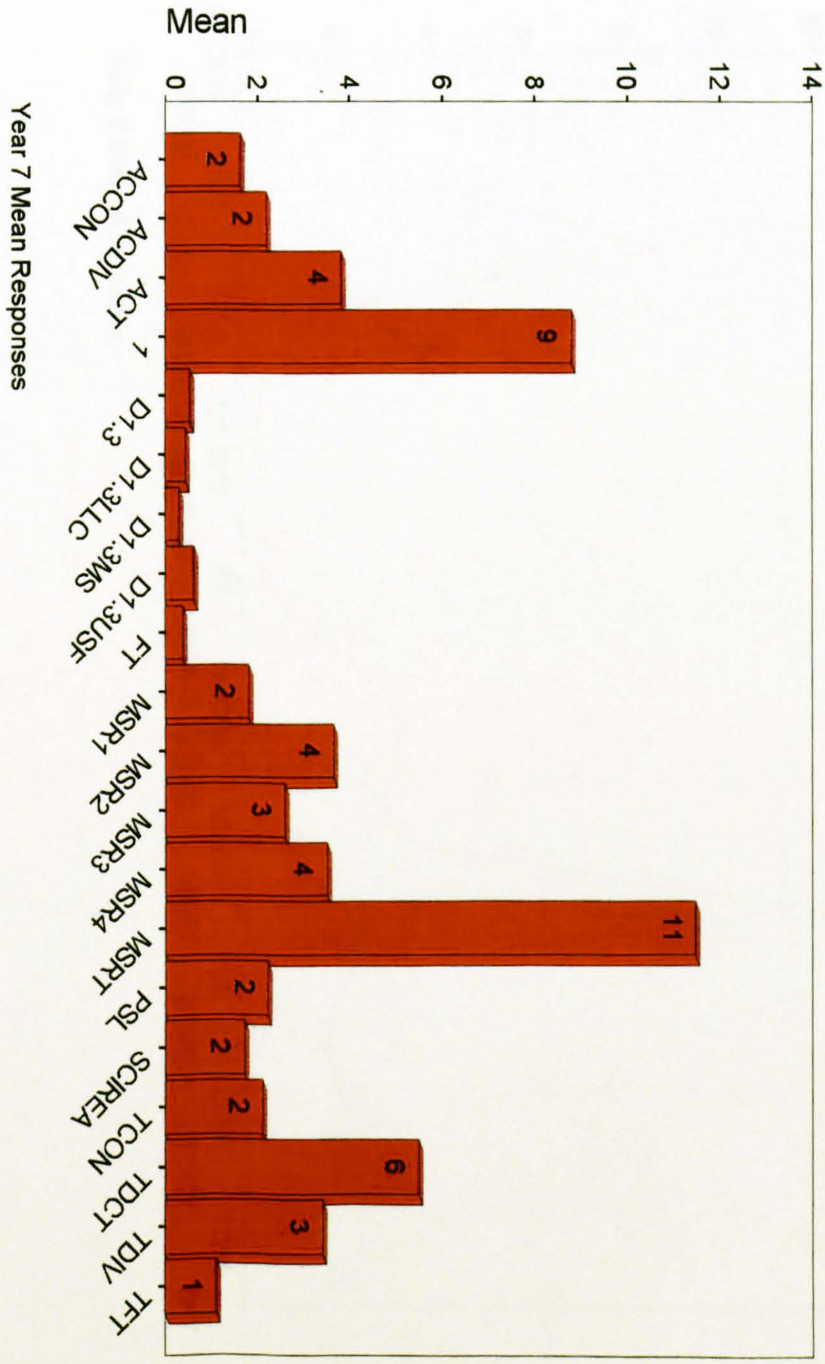


TABLE-6

MEAN RESPONSES YEAR 7 - LINE GRAPH

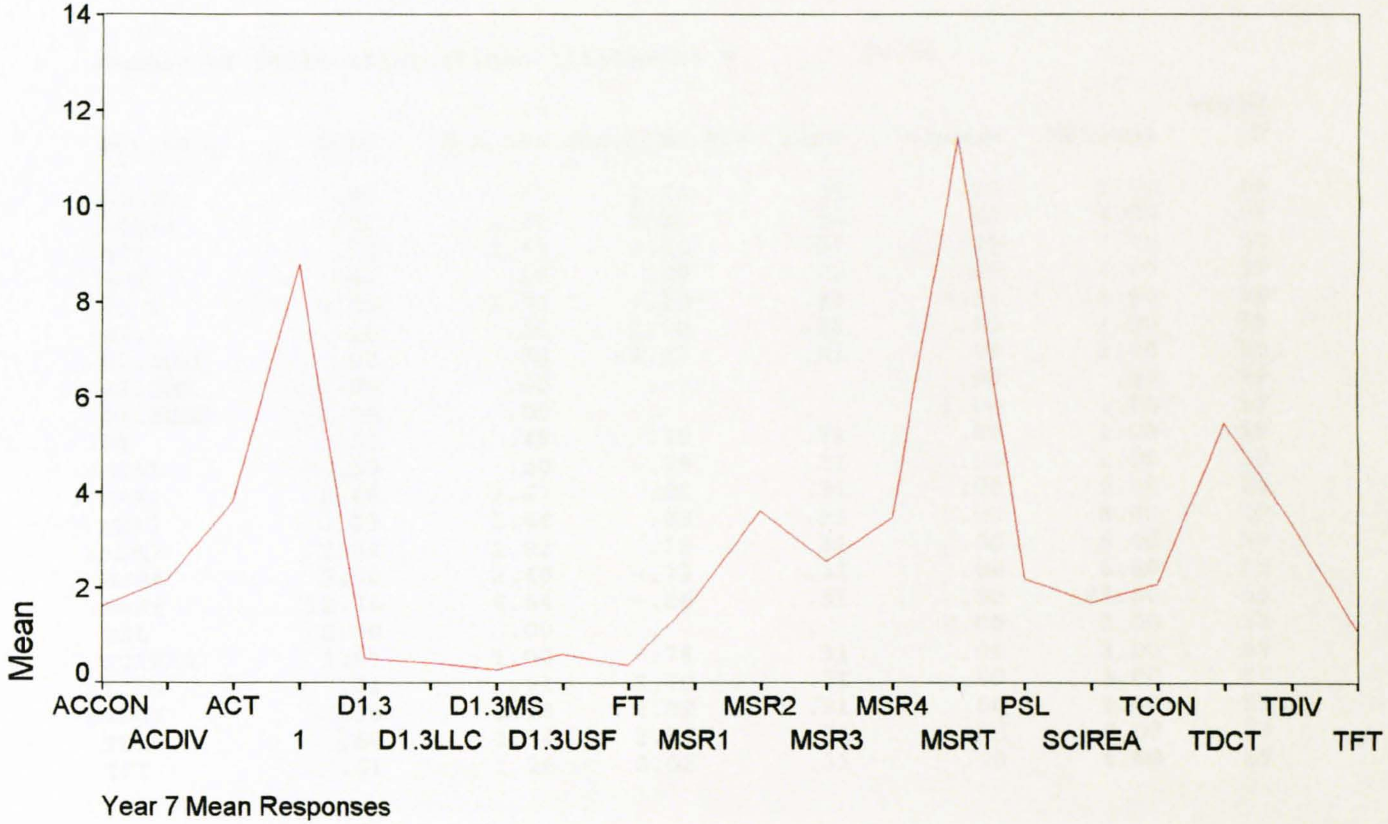


TABLE-7

MEAN AND STANDARD DEVIATION YEAR 8

Number of valid observations (listwise) = 59.00

Variable	Mean	Std Dev	Skewness	S.E. Skew	Minimum	Maximum	Valid N
ACCON	.29	.87	2.78	.31	.00	3.00	59
ACDIV	.42	1.10	2.36	.31	.00	4.00	59
ACT	.71	1.92	2.56	.31	.00	7.00	59
BOY	.41	.50	.39	.31	.00	1.00	59
D1.2	9.56	2.91	-.10	.31	4.00	14.00	59
D1.3	.10	.30	2.70	.31	.00	1.00	59
D1.3LLC	.88	.33	-2.42	.31	.00	1.00	59
D1.3MS	.00	.00	.	.	.00	.00	59
D1.3USF	1.00	.00	.	.	1.00	1.00	59
FT	.34	.48	.70	.31	.00	1.00	59
GIRL	.59	.50	-.39	.31	.00	1.00	59
MSR1	2.68	1.67	.00	.31	.00	6.00	59
MSR2	3.29	2.46	.09	.31	.00	8.00	59
MSR3	2.51	1.92	.10	.31	.00	6.00	59
MSR4	3.90	2.40	-.79	.31	.00	6.00	59
MSRT	12.36	6.64	-.26	.31	.00	23.00	59
PSL	2.00	.00	.	.	2.00	2.00	59
SCIREA	1.61	1.00	-.74	.31	.00	3.00	59
TCON	.31	.91	2.70	.31	.00	3.00	59
TDCT	.98	2.58	2.39	.31	.00	9.00	59
TDIV	.68	1.74	2.24	.31	.00	6.00	59
TFT	.61	1.16	3.02	.31	.00	6.00	59

TABLE-8

HISTOGRAM MEAN RESPONSES - YEAR 8

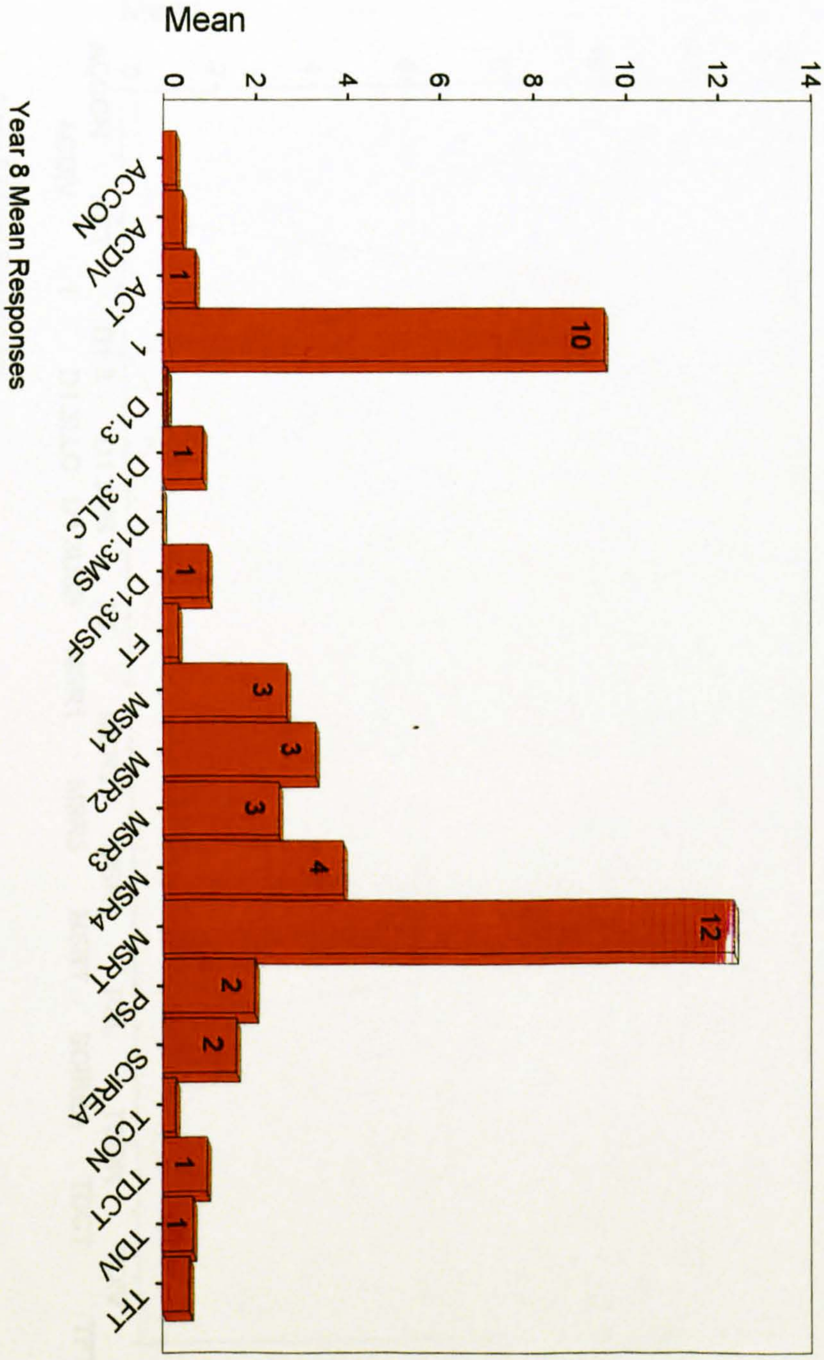
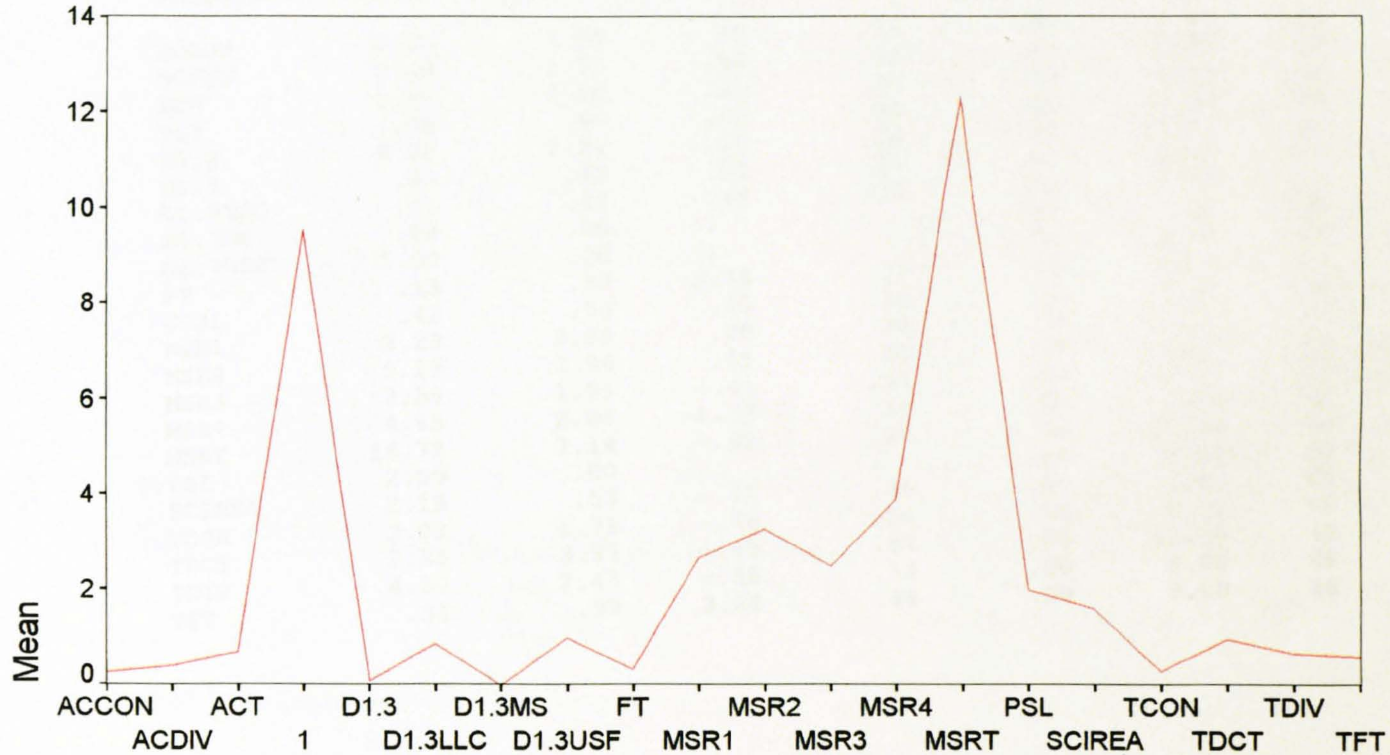


TABLE-9

MEAN RESPONSES YEAR 8 - LINE GRAPH



Year 8 Mean Responses

TABLE 10

MEAN RESPONSES - YEAR 9

Number of valid observations (listwise) = 48.00

Variable	Mean	Std Dev	Skewness	S.E. Skew	Minimum	Maximum	Valid N
ACCON	2.60	1.54	-.86	.34	.00	4.00	48
ACDIV	2.60	1.50	-.90	.34	.00	4.00	48
ACT	5.21	2.90	-.95	.34	.00	8.00	48
BOY	.58	.50	-.35	.34	.00	1.00	48
D1.2	9.50	2.34	-.19	.34	5.00	13.00	48
D1.3	.38	.49	.53	.34	.00	1.00	48
D1.3LLC	.60	.49	-.44	.34	.00	1.00	48
D1.3MS	.00	.00	.	.	.00	.00	48
D1.3USF	1.00	.00	.	.	1.00	1.00	48
FT	.13	.33	2.34	.34	.00	1.00	48
GIRL	.42	.50	.35	.34	.00	1.00	48
MSR1	3.23	2.20	.25	.34	.00	7.00	48
MSR2	5.29	2.96	-.51	.34	.00	8.00	48
MSR3	3.58	1.93	-.41	.34	.00	7.00	48
MSR4	4.85	2.06	-1.78	.34	.00	6.00	48
MSRT	16.79	7.14	-.61	.34	1.00	28.00	48
PSL	2.00	.00	.	.	2.00	2.00	48
SCIREA	2.19	.53	-.71	.34	.00	3.00	48
TCON	3.02	1.71	-.78	.34	.00	5.00	48
TDCT	7.35	3.97	-.85	.34	.00	13.00	48
TDIV	4.33	2.45	-.58	.34	.00	8.00	48
TFT	.31	.99	3.68	.34	.00	5.00	48

Y9

TABLE 11

HISTOGRAM MEAN RESPONSES - YEAR 9

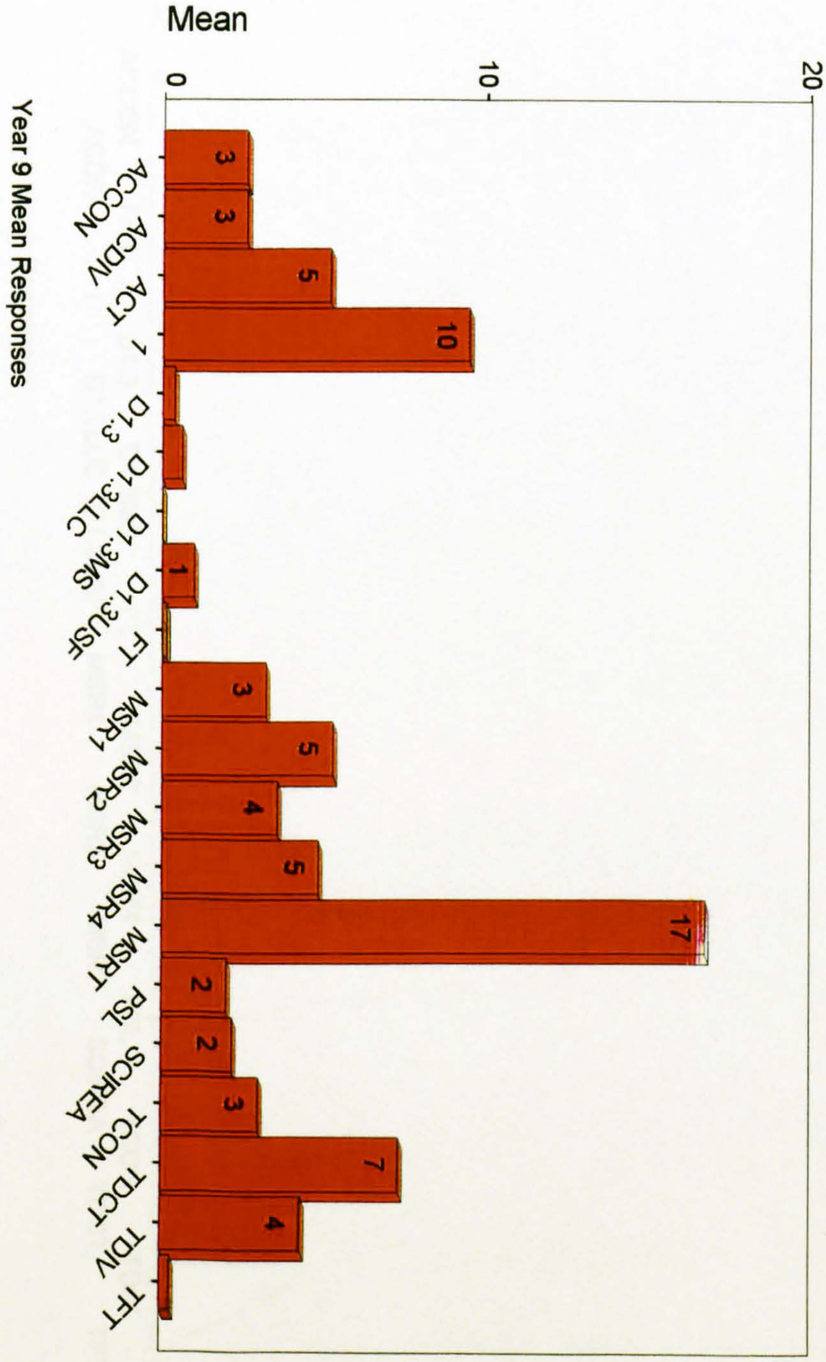
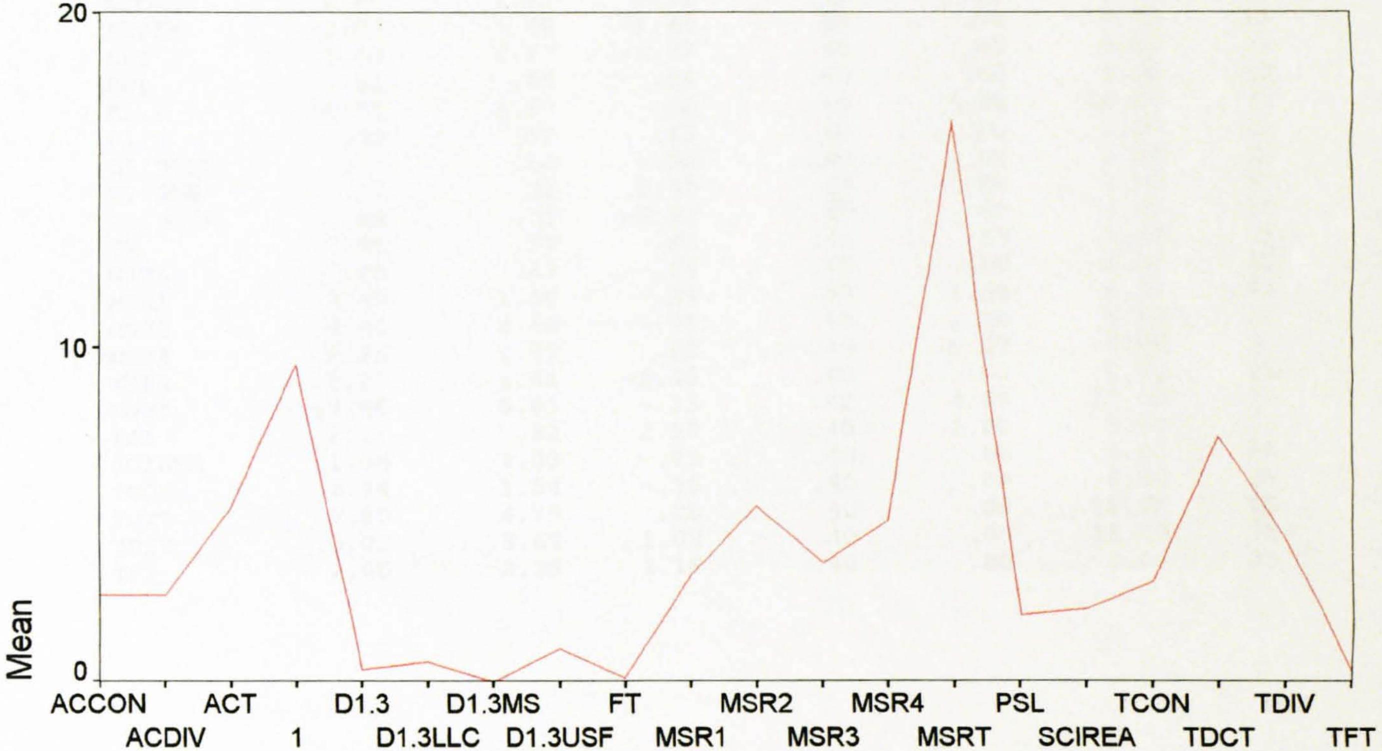


TABLE 12

MEAN RESPONSES YEAR 9 - LINE GRAPH



Year 9 Mean Responses

TABLE 13

MEAN AND STANDARD DEVIATION - YEAR 10

Number of valid observations (listwise) = 35.00

Variable	Mean	Std Dev	Skewness	S.E. Skew	Minimum	Maximum	Valid N
ACCON	2.60	1.42	-.94	.40	.00	4.00	35
ACDIV	3.03	1.48	-1.42	.40	.00	4.00	35
ACT	5.63	2.77	-1.37	.40	.00	8.00	35
BOY	.31	.47	.84	.40	.00	1.00	35
D1.2	10.57	2.97	.40	.40	5.00	16.00	35
D1.3	.40	.50	.43	.40	.00	1.00	35
D1.3LLC	.57	.50	-.30	.40	.00	1.00	35
D1.3MS	.11	.32	2.53	.40	.00	1.00	35
D1.3USF	.89	.32	-2.53	.40	.00	1.00	35
FT	.60	.50	-.43	.40	.00	1.00	35
GIRL	.69	.47	-.84	.40	.00	1.00	35
MSR1	3.40	1.50	-.24	.40	1.00	6.00	35
MSR2	4.46	2.60	-.01	.40	1.00	8.00	35
MSR3	4.26	1.85	.22	.40	1.00	7.00	35
MSR4	5.20	1.41	-2.45	.40	.00	6.00	35
MSRT	17.66	5.81	-.25	.40	4.00	27.00	35
PSL	2.11	.32	2.53	.40	2.00	3.00	35
SCIREA	1.86	1.03	-.89	.40	.00	3.00	35
TCON	2.74	1.54	-.36	.40	.00	6.00	35
TDCT	7.80	4.75	.25	.40	.00	18.00	35
TDIV	5.03	3.62	1.09	.40	.00	15.00	35
TFT	2.00	2.28	1.18	.40	.00	8.00	35

Y10

TABLE 14

HISTOGRAM MEAN RESPONSES - YEAR 10

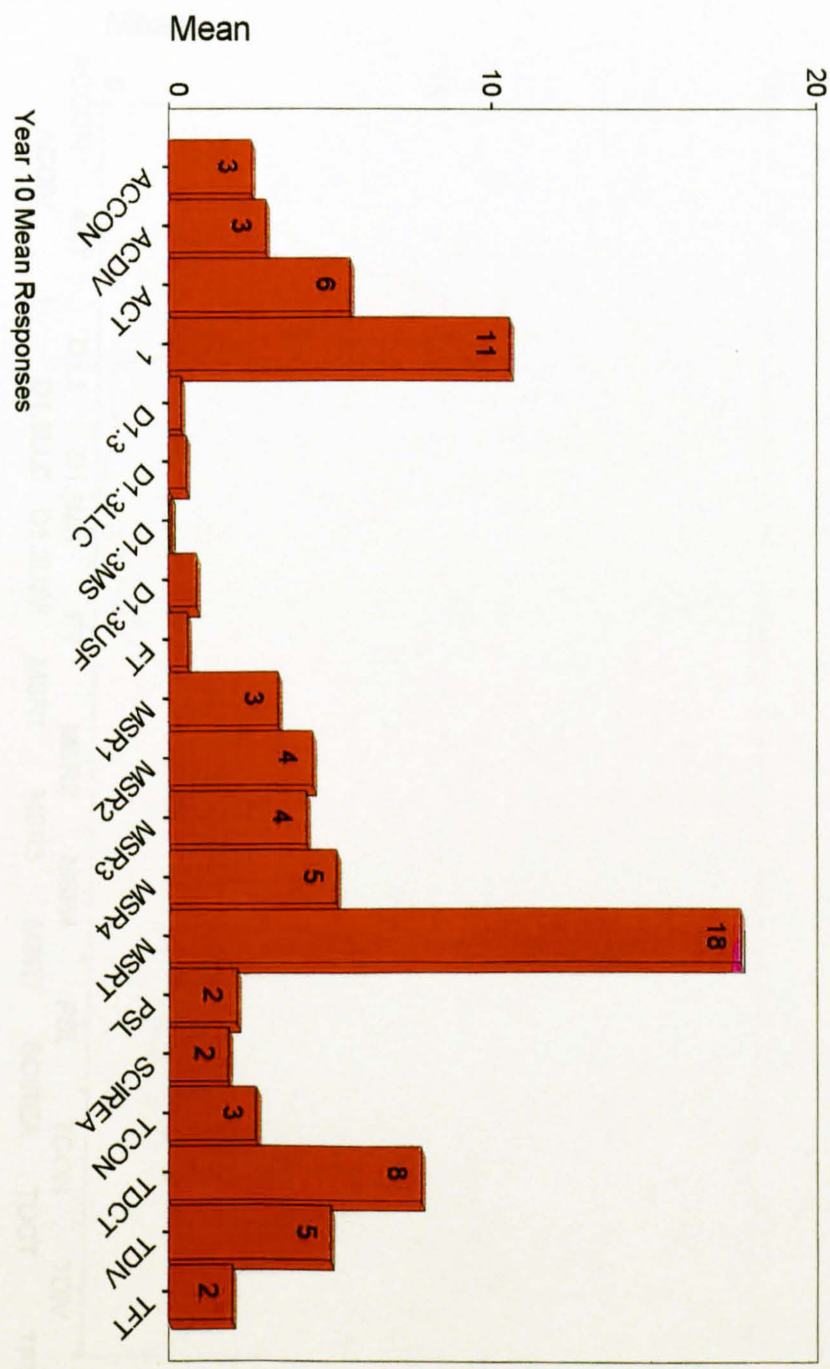
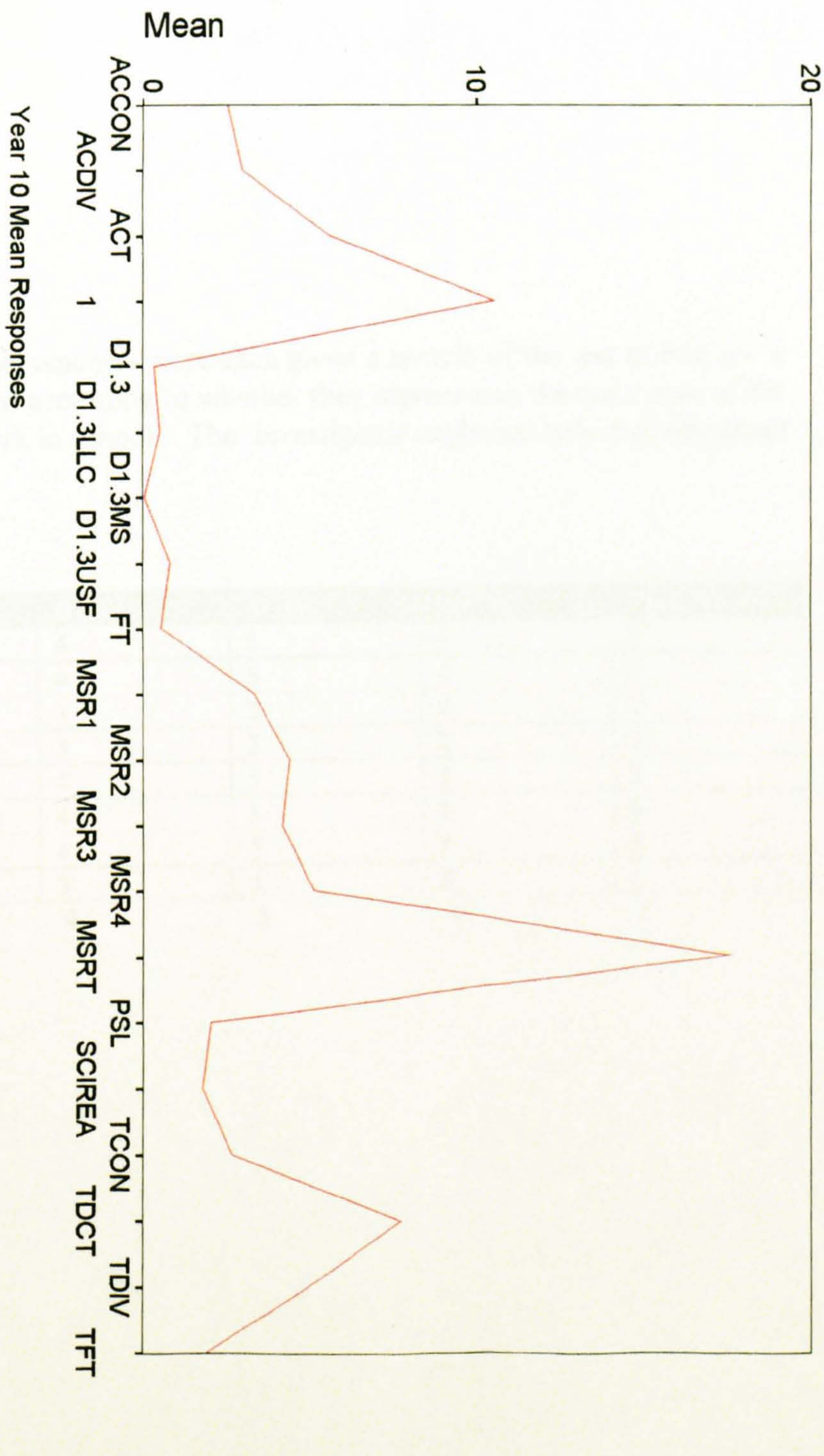


Table 14

TABLE 15

MEAN RESPONSES YEAR 10 - LINE GRAPH



Appendix-7 Teachers Rating of the Tests (Validity)

Nine design and technology teachers were each given a sample of the test to rate on a 1-5 scale (1=Low, 5=High) according to whether they represented the main core of the design and technology work in school . The investigator explained before giving them out.

Teacher	DL2	DL3	M-SR	A/C	Fault Tracing
1	5	4	5	5	5
2	5	4	5	4	5
3	2	3	3	4	1
4	2	3	3	2	1
5	5	4	5	5	3
6	3	4	3	3	4
7	5	4	5	5	5
8	5	3	5	5	3
9	5	4	5	4	3

Appendix-8 Average Test Reliability

```
24 Aug 97 SPSS for MS WINDOWS Release 6.0                              Page 4

 R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

  1.     ACCON
  2.     ACDIV
  3.     ACT
  4.     D1.2             1
  5.     D1.3
  6.     D1.3LLC
  7.     D1.2MS
  8.     D1.2USF
  9.     FT
 10.     MSR1
 11.     MSR2
 12.     MSR3
 13.     MSR4
 14.     MSRT
 15.     SCIREA


Reliability Coefficients

N of Cases =    197.0                       N of Items = 15

Alpha =    .7861
```

Appendix-9 Chi-Square Test Results

Chi Square Test

- - - - - Chi-Square Test

ACCON LFS

Category	Cases Observed	Expected	Residual
.00	94	39.40	54.60
1.00	6	39.40	-33.40
2.00	6	39.40	-33.40
3.00	59	39.40	19.60
4.00	32	39.40	-7.40
Total	197		

Chi-Square	D.F.	Significance
143.4315	4	.0000

- - - - - Chi-Square Test

ACT LFS

Category	Cases Observed	Expected	Residual
.00	83	21.89	61.11
1.00	2	21.89	-19.89
2.00	7	21.89	-14.89
3.00	4	21.89	-17.89
4.00	7	21.89	-14.89
5.00	7	21.89	-14.89
6.00	23	21.89	1.11
7.00	41	21.89	19.11
8.00	23	21.89	1.11
Total	197		

Chi-Square	D.F.	Significance
250.4873	8	.0000

Chi Square Test

- - - - - Chi-Square Test

ACDIV

Category	Cases Observed	Expected	Residual
.00	84	39.40	44.60
1.00	5	39.40	-34.40
2.00	12	39.40	-27.40
3.00	36	39.40	-3.40
4.00	60	39.40	20.60

Total	197		

Chi-Square	D.F.	Significance
110.6396	4	.0000

- - - - - Chi-Square Test

D1.2 1 LC/EF

Category	Cases Observed	Expected	Residual
3.00	1	14.07	-13.07
4.00	2	14.07	-12.07
5.00	13	14.07	-1.07
6.00	15	14.07	.93
7.00	19	14.07	4.93
8.00	26	14.07	11.93
9.00	25	14.07	10.93
10.00	22	14.07	7.93
11.00	21	14.07	6.93
12.00	21	14.07	6.93
13.00	19	14.07	4.93
14.00	7	14.07	-7.07
15.00	2	14.07	-12.07
16.00	4	14.07	-10.07

Total	197		

Chi-Square	D.F.	Significance
77.1015	13	.0000

Chi Square Test

- - - - - Chi-Square Test

D1.3 EF/LF (4/5)

Category	Cases Observed	Expected	Residual
.00	129	98.50	30.50
1.00	68	98.50	-30.50
Total	197		

Chi-Square	D.F.	Significance
18.8883	1	.0000

- - - - - Chi-Square Test

D1.3LLC LC (3)

Category	Cases Observed	Expected	Residual
.00	71	98.50	-27.50
1.00	126	98.50	27.50
Total	197		

Chi-Square	D.F.	Significance
15.3553	1	.0001

- - - - - Chi-Square Test

D1.3MS EF (4)

Category	Cases Observed	Expected	Residual
.00	176	98.50	77.50
1.00	21	98.50	-77.50
Total	197		

Chi-Square	D.F.	Significance
121.9543	1	.0000

Chi Square Test

- - - - - Chi-Square Test

D1.3USF, L/C

Category	Cases Observed	Expected	Residual
.00	24	98.50	-74.50
1.00	173	98.50	74.50
Total	197		

12 %

Chi-Square	D.F.	Significance
112.6954	1	.0000

- - - - - Chi-Square Test

FT LC/LF

Category	Cases Observed	Expected	Residual
.00	128	98.50	29.50
1.00	69	98.50	-29.50
Total	197		

Chi-Square	D.F.	Significance
17.6701	1	.0000

- - - - - Chi-Square Test

MSR1

Category	Cases Observed	Expected	Residual
.00	22	24.63	-2.63
1.00	35	24.63	10.38
2.00	46	24.63	21.38
3.00	25	24.63	.38
4.00	32	24.63	7.38
5.00	24	24.63	-.63
6.00	9	24.63	-15.63
7.00	4	24.63	-20.63
Total	197		

Chi-Square	D.F.	Significance
52.6244	7	.0000

Chi Square Test

- - - - - Chi-Square Test

MSR2

Category	Cases Observed	Expected	Residual
.00	23	21.89	1.11
1.00	16	21.89	-5.89
2.00	25	21.89	3.11
3.00	23	21.89	1.11
4.00	29	21.89	7.11
5.00	17	21.89	-4.89
6.00	14	21.89	-7.89
7.00	15	21.89	-6.89
8.00	35	21.89	13.11

Total	197		

Chi-Square	D.F.	Significance
18.4061	8	.0184

- - - - - Chi-Square Test

MSR3

Category	Cases Observed	Expected	Residual
.00	25	24.63	.38
1.00	16	24.63	-8.63
2.00	41	24.63	16.38
3.00	27	24.63	2.38
4.00	36	24.63	11.38
5.00	31	24.63	6.38
6.00	13	24.63	-11.63
7.00	8	24.63	-16.63

Total	197		

Chi-Square	D.F.	Significance
37.7614	7	.0000

Chi Square Test

- - - - - Chi-Square Test

MSR4

Category	Cases Observed	Expected	Residual
.00	30	28.14	1.86
1.00	2	28.14	-26.14
2.00	8	28.14	-20.14
3.00	16	28.14	-12.14
4.00	21	28.14	-7.14
5.00	32	28.14	3.86
6.00	88	28.14	59.86

Total	197		

Chi-Square	D.F.	Significance
173.7157	6	.0000

Chi Square Test

- - - - - Chi-Square Test

MSRT

Category	Cases Observed	Expected	Residual
.00	5	7.04	-2.04
1.00	6	7.04	-1.04
3.00	7	7.04	-.04
4.00	4	7.04	-3.04
5.00	4	7.04	-3.04
6.00	3	7.04	-4.04
7.00	3	7.04	-4.04
8.00	8	7.04	.96
9.00	11	7.04	3.96
10.00	9	7.04	1.96
11.00	14	7.04	6.96
12.00	10	7.04	2.96
13.00	8	7.04	.96
14.00	13	7.04	5.96
15.00	5	7.04	-2.04
16.00	9	7.04	1.96
17.00	5	7.04	-2.04
18.00	11	7.04	3.96
19.00	12	7.04	4.96
20.00	8	7.04	.96
21.00	1	7.04	-6.04
22.00	16	7.04	8.96
23.00	9	7.04	1.96
24.00	10	7.04	2.96
25.00	1	7.04	-6.04
26.00	1	7.04	-6.04
27.00	3	7.04	-4.04
28.00	1	7.04	-6.04

Total	197		

Chi-Square	D.F.	Significance
68.0761	27	.0000

Chi Square Test

```
- - - - - Chi-Square Test

    PSL

                     Cases
      Category    Observed   Expected   Residual

          .00           2      65.67     -63.67
         2.00         174      65.67     108.33
         3.00          21      65.67     -44.67
                      ---
         Total        197

         Chi-Square              D.F.         Significance
          270.8325                 2              .0000

- - - - - Chi-Square Test

    SCIREA

                     Cases
      Category    Observed   Expected   Residual

          .00          35      65.67     -30.67
         2.00         126      65.67      60.33
         3.00          36      65.67     -29.67
                      ---
         Total        197

         Chi-Square              D.F.         Significance
           83.1574                 2              .0000
```

Concrete / Formal

E/F/LF

Chi Square Test

- - - - - Chi-Square Test

ACCON (LF)

Category	Cases Observed	Expected	Residual
.00	94	39.40	54.60
1.00	6	39.40	-33.40
2.00	6	39.40	-33.40
3.00	59	39.40	19.60
4.00	32	39.40	-7.40

Total	197		

Chi-Square	D.F.	Significance
143.4315	4	.0000

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Appendix-10 One-way Analysis of Variance

(a) Factor-1 General Intelligence/Ability

----- O N E W A Y -----

Variable TDCT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	4.0232	4.0232	.2163	.6431
Within Groups	81	1506.5792	18.5997		
Total	82	1510.6024			

----- O N E W A Y -----

Variable TDIV
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	9.7836	9.7836	1.0891	.2998
Within Groups	81	727.6381	8.9832		
Total	82	737.4217			

----- O N E W A Y -----

Variable ACCON
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0004	.0004	.0002	.990(
Within Groups	81	179.8792	2.2207		
Total	82	179.8795			

----- O N E W A Y -----

Variable ACDIV
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	3.6458	3.6458	1.6365	.204!
Within Groups	81	180.4506	2.2278		
Total	82	184.0964			

----- O N E W A Y -----

Variable ACT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	3.5746	3.5746	.4427	.507'
Within Groups	81	654.0881	8.0752		
Total	82	657.6627			

----- O N E W A Y -----

Variable TCON
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1.5640	1.5640	.5820	.4477
Within Groups	81	217.6649	2.6872		
Total	82	219.2289			

----- O N E W A Y -----

ɔle ACT
ɔle GROUP Group

Analysis of Variance

rce	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
ups	1	535.1218	535.1218	92.4113	.0000
ps	105	608.0184	5.7907		
	106	1143.1402			

----- O N E W A Y -----

Variable TCON
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	195.2039	195.2039	110.5002	.000(
Within Groups	105	185.4876	1.7665		
Total	106	380.6916			

----- O N E W A Y -----

Variable TDCT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	1074.3368	1074.3368	100.3640	.00(
Within Groups	105	1123.9622	10.7044		
Total	106	2198.2991			

----- O N E W A Y -----

Variable TDIV
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	353.6482	353.6482	81.1567	.000(
Within Groups	105	457.5480	4.3576		
Total	106	811.1963			

----- O N E W A Y -----

Variable TDCT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	583.1048	583.1048	44.8318	.0000
Within Groups	112	1456.7285	13.0065		
Total	113	2039.8333			

----- O N E W A Y -----

Variable TDIV
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	216.5826	216.5826	40.4012	.0000
Within Groups	112	600.4086	5.3608		
Total	113	816.9912			

----- O N E W A Y -----

Variable ACCON
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	141.9705	141.9705	95.8145	.0000
Within Groups	105	155.5809	1.4817		
Total	106	297.5514			

----- O N E W A Y -----

Variable ACDIV
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	125.8337	125.8337	75.1199	.0000
Within Groups	105	175.8859	1.6751		
Total	106	301.7196			

----- O N E W A Y -----

Variable ACCON
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	51.7412	51.7412	32.4053	.000
Within Groups	112	178.8290	1.5967		
Total	113	230.5702			

----- O N E W A Y -----

Variable ACDIV
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	89.8108	89.8108	43.1326	.000
Within Groups	112	233.2068	2.0822		
Total	113	323.0175			

----- O N E W A Y -----

Variable ACT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	277.8886	277.8886	41.0802	.00
Within Groups	112	757.6290	6.7645		
Total	113	1035.5175			

----- O N E W A Y -----

Variable TCON
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	94.5140	94.5140	39.4076	.00
Within Groups	112	268.6176	2.3984		
Total	113	363.1316			

(b) Factor-2 Perceptual Analysis/Spatial Ability

----- ONEWAY -----

Variable MSR3
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	30.5782	30.5782	8.2662	.0049
Within Groups	105	388.4124	3.6992		
Total	106	418.9907			

----- ONEWAY -----

Variable MSR4
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	24.1824	24.1824	4.7428	.0317
Within Groups	105	535.3690	5.0988		
Total	106	559.5514			

----- ONEWAY -----

Variable MSRT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	520.7635	520.7635	11.0388	.0012
Within Groups	105	4953.4421	47.1756		
Total	106	5474.2056			

- - - - - O N E W A Y - - - - -

Variable D1.2 1
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0931	.0931	.0130	.9093
Within Groups	105	750.5424	7.1480		
Total	106	750.6355			

- - - - - O N E W A Y - - - - -

Variable MSR1
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.5907	.5907	.1580	.6921
Within Groups	81	302.8792	3.7392		
Total	82	303.4699			

- - - - - O N E W A Y - - - - -

Variable MSR2
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	14.0964	14.0964	1.7769	.186
Within Groups	81	642.6024	7.9334		
Total	82	656.6988			

----- O N E W A Y -----

Variable MSR3
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	9.1898	9.1898	2.5461	.1145
Within Groups	81	292.3524	3.6093		
Total	82	301.5422			

----- O N E W A Y -----

Variable MSR4
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	2.4208	2.4208	.7328	.3945
Within Groups	81	267.5792	3.3034		
Total	82	270.0000			

----- O N E W A Y -----

Variable MSRT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	15.1615	15.1615	.3467	.5576
Within Groups	81	3541.8024	43.7260		
Total	82	3556.9639			

----- O N E W A Y -----

Variable MSR2
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	106.2433	106.2433	14.6012	.0002
Within Groups	105	764.0184	7.2764		
Total	106	870.2617			

----- ONEWAY -----

Variable D1.2 1
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	23.2358	23.2358	3.3695	.0701
Within Groups	81	558.5714	6.8959		
Total	82	581.8072			

----- ONEWAY -----

Variable MSR1
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob
Between Groups	1	21.0421	21.0421	8.9587	.003
Within Groups	112	263.0632	2.3488		
Total	113	284.1053			

----- ONEWAY -----

Variable MSR2
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	3.8216	3.8216	.6724	.414
Within Groups	112	636.5381	5.6834		
Total	113	640.3596			

----- ONEWAY -----

Variable MSR1
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	8.0413	8.0413	2.1797	.142
Within Groups	105	387.3605	3.6891		
Total	106	395.4019			

----- ONEWAY -----

Variable MSR3
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.2384	.2384	.0768	.7823
Within Groups	112	347.9458	3.1067		
Total	113	348.1842			

----- ONEWAY -----

Variable MSR4
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	4.3121	4.3121	.8576	.3564
Within Groups	112	563.1353	5.0280		
Total	113	567.4474			

----- ONEWAY -----

Variable MSRT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	21.2993	21.2993	.5283	.4688
Within Groups	112	4515.2709	40.3149		
Total	113	4536.5702			

----- ONEWAY -----

Variable D1.2 1
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	16.4120	16.4120	2.0530	.1547
Within Groups	112	895.3424	7.9941		
Total	113	911.7544			

(c) Factor-3 Function/Structure

----- O N E W A Y -----

Variable D1.3MS
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.2644	.2644	6.0443	.0161
Within Groups	81	3.5429	.0437		
Total	82	3.8072			

----- O N E W A Y -----

Variable D1.3USF
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.2644	.2644	6.0443	.0161
Within Groups	81	3.5429	.0437		
Total	82	3.8072			

----- O N E W A Y -----

Variable PSL
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.2644	.2644	6.0443	.0161
Within Groups	81	3.5429	.0437		
Total	82	3.8072			

----- O N E W A Y -----

Variable D1.3MS
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0000	.0000	.	.
Within Groups	105	.0000	.0000		
Total	106	.0000			

----- O N E W A Y -----

Variable D1.3USF
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0000	.0000	.	.
Within Groups	105	.0000	.0000		
Total	106	.0000			

----- O N E W A Y -----

Variable PSL
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0000	.0000	.	.
Within Groups	105	.0000	.0000		
Total	106	.0000			

----- ONEWAY -----

Variable D1.3MS
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	2.7195	2.7195	25.9317	.0000
Within Groups	112	11.7455	.1049		
Total	113	14.4649			

----- ONEWAY -----

Variable D1.3USF
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	3.7640	3.7640	33.1228	.0000
Within Groups	112	12.7273	.1136		
Total	113	16.4912			

----- ONEWAY -----

Variable PSL
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1.5903	1.5903	8.1228	.0052
Within Groups	112	21.9273	.1958		
Total	113	23.5175			

(d) Factor-4 Practical Ability

----- O N E W A Y -----

Variable D1.3
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1.9770	1.9770	12.4751	.0006
Within Groups	105	16.6398	.1585		
Total	106	18.6168			

----- O N E W A Y -----

Variable D1.3LLC
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0217	.0217	.0876	.7680
Within Groups	81	20.0506	.2475		
Total	82	20.0723			

----- O N E W A Y -----

Variable D1.3
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.0127	.0127	.0521	.8199
Within Groups	81	19.6500	.2426		
Total	82	19.6627			

----- O N E W A Y -----

Variable D1.3LLC
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	5.1854	5.1854	29.3227	.0000
Within Groups	112	19.8059	.1768		
Total	113	24.9912			

----- O N E W A Y -----

Variable D1.3
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	5.6054	5.6054	32.9968	.0000
Within Groups	112	19.0262	.1699		
Total	113	24.6316			

----- O N E W A Y -----

Variable D1.3LLC
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	2.0336	2.0336	12.0987	.0007
Within Groups	105	17.6487	.1681		
Total	106	19.6822			

(e) Factor-6 Logical/Systematic

----- O N E W A Y -----

Variable TFT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	2.3452	2.3452	1.9803	.1623
Within Groups	105	124.3464	1.1843		
Total	106	126.6916			

----- O N E W A Y -----

Variable FT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	4.5669	4.5669	27.1001	.0000
Within Groups	81	13.6500	.1685		
Total	82	18.2169			

----- O N E W A Y -----

Variable TFT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	57.6393	57.6393	21.0010	.0000
Within Groups	81	222.3125	2.7446		
Total	82	279.9518			

----- O N E W A Y -----

Variable FT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	.1060	.1060	.4493	.5041
Within Groups	112	26.4203	.2359		
Total	113	26.5263			

----- O N E W A Y -----

Variable TFT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	7.6114	7.6114	5.1935	.0246
Within Groups	112	164.1430	1.4656		
Total	113	171.7544			

----- O N E W A Y -----

Variable FT
By Variable GROUP Group

Analysis of Variance

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	1.2119	1.2119	6.8894	.0100
Within Groups	105	18.4703	.1759		
Total	106	19.6822			

Appendix-11 Design Process Illustrations

(a) Technological Process Matrix

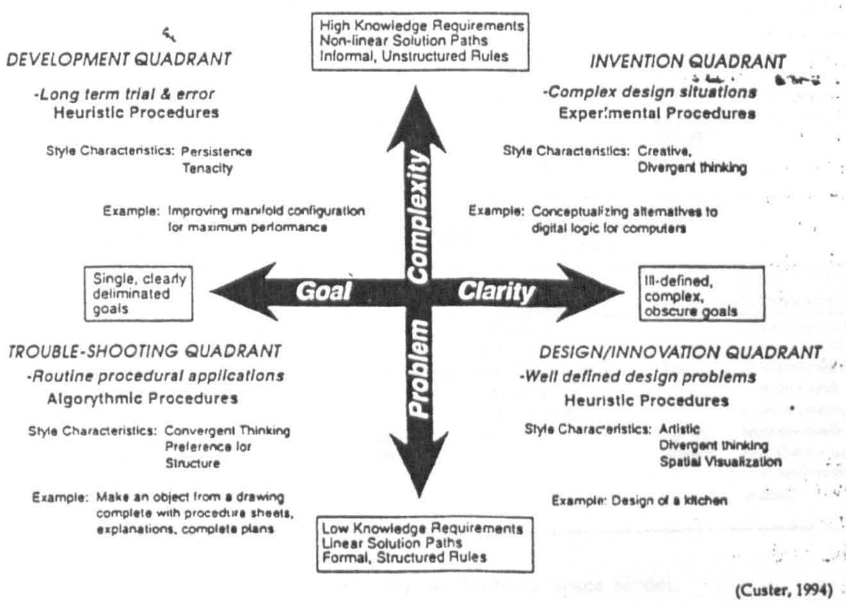


Fig. 5. Technological Process Matrix.

(b) Problem Space Model

Technological Problem Space

Resources		Primary Processes		Goal Thrust (Motivation)
Technological Knowledge Non-technological Knowledge Creative Energy Ingenuity Persistence Experience/capability Materials Tools, Etc.	are directed specifically at	Designing Making Trouble-shooting Repairing Inventing Improving Developing Etc.	To Yield	Artifacts (including physical human made objects as well as programs which drive physical objects)

Social/Personal Problem Space

Resources		Primary Processes		Goal Thrust (Motivation)
Social Science Knowledge Non-social science knowledge Creative Energy Ingenuity Persistence Experience/capability Etc.	are directed specifically at	resolving negotiating organizing planning directing counseling nurturing interacting, etc.	To Yield	healthy, efficient, satisfying, meaningful interpersonal and intrapersonal relationships (including cultures and nations)

Natural/Ecological Problem Space

Resources		Primary Processes		Goal Thrust (Motivation)
Scientific Knowledge Non-natural science knowledge Creative Energy Ingenuity Persistence Experience/capability Etc.	are directed specifically at	researching observing hypothesis testing exploring investigating etc.	To Yield	understanding of natural world and homeostasis (between humans and environment, between human made artifacts and the natural world, and within the natural world)

(Custer, 1994)

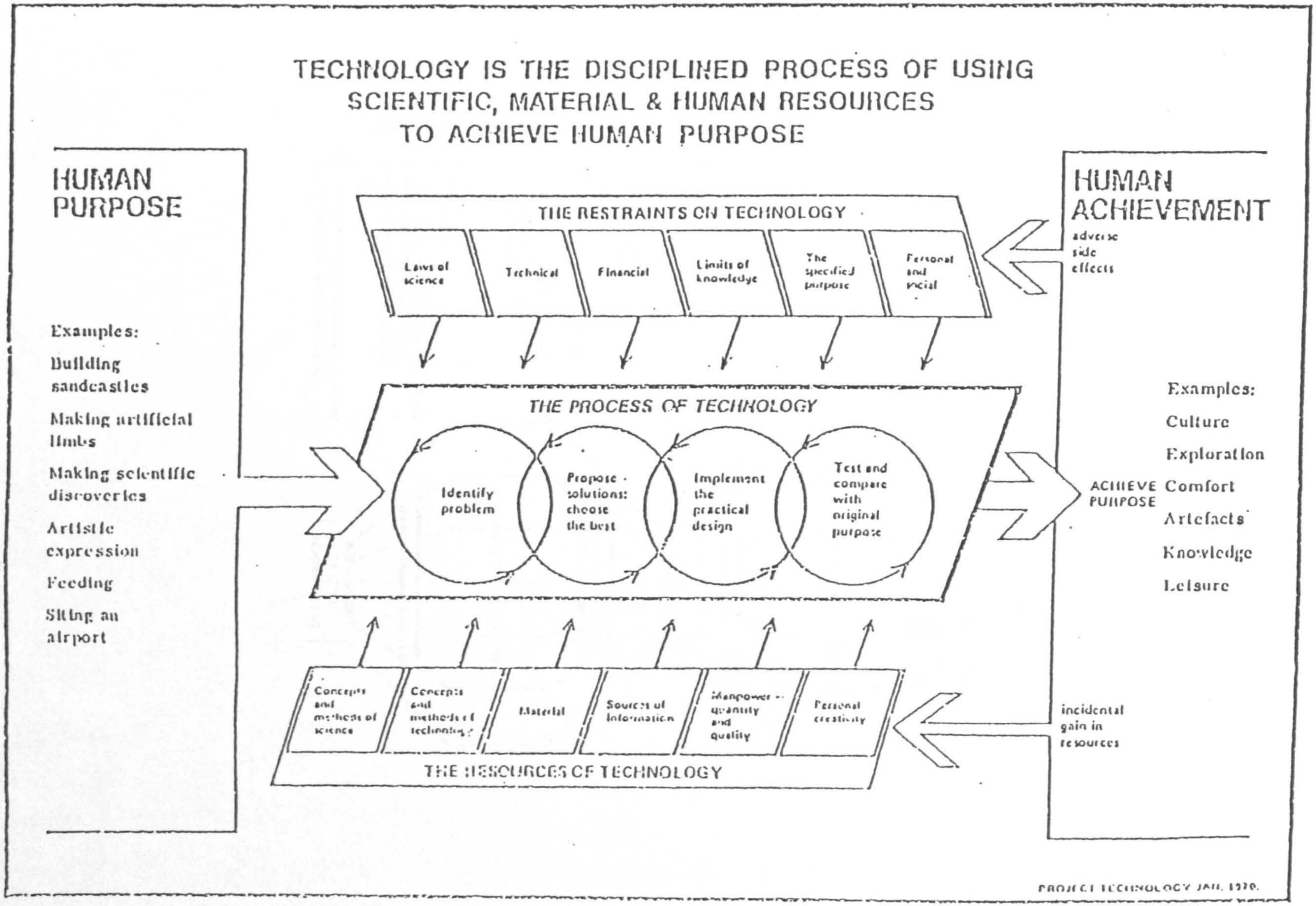
Fig. 4. Problem Space Model.

TABLE . Models of the design/problem-solving process

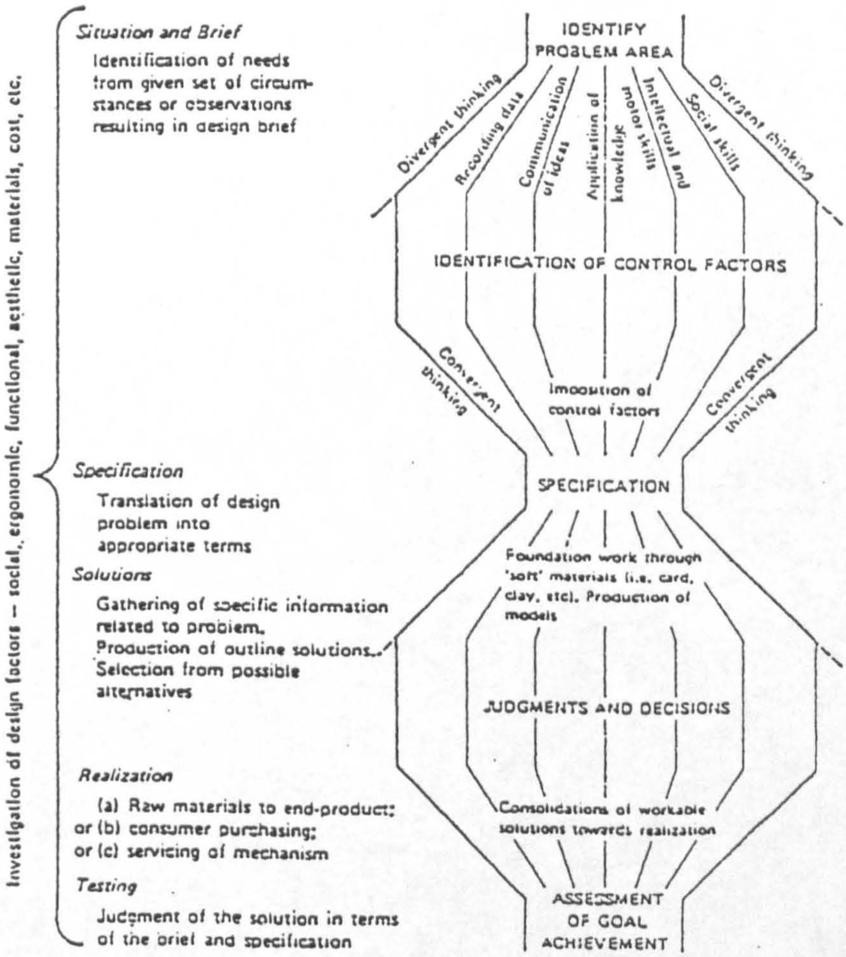
	1	2	3	4	5	6	7	8	9
Process skill	Design and craft education project. Design for Today (1971)	How designers think. Lawson (1980)	Understanding design and technology. APU (1981)	Design and technology 5–12. Williams, P. and Jinks, D. (1985)	Problem solving: science and technology in the primary school. Engineering Council. SCSST (1985) The problem solving process	Problem solving: science and technology in primary schools. Engineering Council. SCSST (1985) – (establishment of a successful new product in commerce and industry)	Craft, design and technology from 5 to 16. DES (1987)	Design and primary education. Design Council (1987)	APU Design and Technological Activity – A framework for assessment. HMSO (1987)
Identifying	Identify problem area. Identification of needs from given set of circumstances or observations resulting in design brief.		Recognising the existence of a problem which might be amenable to solution through D&T activity.		Recognising problems.	Identifying and specifying a market need.	Recognise the general problem area.	Identify the need to be met.	
Clarifying	Identification of control factors. Imposition of control factors.	Briefing.	Employing knowledge, analysis, skills and judgement in clarifying the problem.	Problem need.			Specify the exact need. Write the brief.		Speculating in the mind's eye togehter with informal sketch-drawing and modelling.
Specifying	Specification. Translation of design problem into appropriate terms.	Analysis (ordering and structuring of problem).	Matching the proposed product with its purpose.				Write 'the specification'.		
Researching	Gathering of specific information related to problem.		Looking for relevant information and resources.	Research development.		Research and development.	Research. Collect data.	Assemble any relevant information.	
Generating	Production of outline solutions.	Synthesis (generating of a solution).	Thinking of alternative solutions.	First ideas.	Discussing or thinking about solving them.		Generate ideas and share thoughts with other helpful agencies.		
Selecting	Selection from possible alternatives.		Choosing the best from these.	Chosen idea.	Trying out one solution.	Selection of the optimum solution from a number of options.	Select and formulate the design proposals.		Exploring and developing ideas inside the head.
Modelling	Foundation work through "soft" materials, i.e. card, clay etc. Production of models.		Initiating and developing ideas and images and manipulating those images modelling these images in a variety of ways.			More detailed design and material selection.	Model ideas and test them.		More formalised sketching drawing and experimental modelling.
Planning			Planning the practical activity. Selecting resources.			Manufacturing process defined.	Detail intentions and plan manufacture. Relate the methods of making to the facilities and resources available, making any necessary adjustments.		
Making	Consolidation of workable solutions towards realisation.	—	Using tools, instruments, materials, components, appliances and energy resources.	Making.		Manufacturing processes implemented.	Make the solution, refining the proposal as necessary.		Refining and detailing in the head together with prototyping.
Testing	Judgements and decisions.		Testing the performance of a given product.	Testing, evaluate.	Assessing how effective it is.	Trials.	Test the outcome.		Validating and judging inside the head toget with testing.
Modifying				Alteration	Perhaps modifying the solution in the light of experience.		Adjust if possible.		Modifying.
Evaluating	Assessment of goal achievement. Judgement of the solution in terms of the brief and the specification.	Evaluation (critical evaluation of suggested solution).	Monitoring effects of operations controlling outcomes understanding context in which product to be used; identifying the criteria by which it should be judged; choosing measures; forming judgements; distinguishing needs assigning priorities; appraising efficacy of design activity	Acceptance, rejection		Evaluations.	Evaluate the outcome against the original need.	Evaluate the effectiveness of the solution.	
Selling						'Sale and use'.			

TABLE .. (Continued)

Process skill	10 GCSE teacher's guide for craft design and technology, in APU Design and Technological Activity – A framework for assessment, HMSO (1987) (Cyclical diagram)	11 Science for ages 5 to 16 – Proposals of the Secretary of State DES (1988)	12 Design and technology through problem solving, Johnsey R. (1990)	13 Technology in the National Curriculum Non-statutory guidance, NCC (1990)	14 The assessment of performance in Design and Technology, Kimbell *et al.* (1991)	15 The Investigative Learning Process in Design and Technology Teaching Vol. 24, No. 1, Sellwood P. (1991)	16 Technology for ages 5 to 16 – Proposals of the Secretary of State for Education, DFE (1992)	17 Design and Technology in the National Curriculum (Key Stage 1), DFE (1995)
Identifying	Observing a context.	Observation investigation and enquiry. Recording.		Identifying needs and opportunities for activities by investigating a range of contexts.	Hazy impressions inside head.	What is the problem?	Investigating, clarifying.	. . . generate ideas.
Clarifying	Detailing a problem.		Define problem.				Specifying the design task.	. . . clarify their ideas.
Specifying								
Researching	Research.		Research problem.					
Generating	Exploring possibilities.	Designing . . . children explore possible solutions.	Consider a number of solutions.			What possible solutions are there? Choose 'possible' solutions.		
Selecting	Refining ideas (More information may be needed before refinement is possible.)	. . . one is selected for development.		Producing a design proposal a.	Discussion, drawings, sketches diagrams, notes, graphs, numbers outside head. Speculating exploring inside head.	What solution is the most appropriate?		
Modelling	Detailing a solution (Ideas may have to be detailed before they can be rejected.)		Design device, or make plan, on paper.	Developing it into a realistic design.	Modelling in solid to predict or represent reality outside head. Clarifying and validating.		Modelling, developing and communicating design ideas.	. . . develop ide through shaping assembling and rearranging materials . . . . . . develop an communicate id by modelling .
Planning	Planning the making.			Planning			Planning and organising the making.	. . . make sugg tions about how proceed . . . se materials, tools and techniques.
Making	Making (Making processes may have to be researched.)	Making . . . children will plan how they will interpret their designs into three dimensional form.	Make device or carry out plan.	Making design and technology products.	Prototyping or providing solutions outside head.	Try out your chosen solution.	Using a variety of materials, components, tools, equipment and processes to make products safely.	. . . measure, m out, cut, shape, assemble join : combine a rang materials . . . a simple finishin techniques.
Testing			Test device or plan.			Test your solution. Evaluate the results.	Testing.	
Modifying		. . . design may need to be modified . . .	Improve device or plan.			Modify if necessary.	Modifying.	
Evaluating	Evaluation (Evaluation usually leads to refining of ideas).	Evaluating Children should evaluate the outcome to see if it satisfies the original intention.		Evaluating the processes, products and effects of their activities and those of others.	Critical appraisal inside head.		Evaluating.	. . . consider de ideas as these develop and identify streng and weaknesse . . . evaluate t products, identifying strengths and weaknesses.
Selling								



(Harrison, C.E. 1970)



Investigation of design factors — social, ergonomic, functional, aesthetic, materials, cost, etc.
Situation and Brief
Identification of needs from given set of circumstances or observations resulting in design brief
Specification
Translation of design problem into appropriate terms
Solutions
Gathering of specific information related to problem.
Production of outline solutions.
Selection from possible alternatives
Realization
(a) Raw materials to end-product;
or (b) consumer purchasing;
or (c) servicing of mechanism
Testing
Judgement of the solution in terms of the brief and specification
IDENTIFY PROBLEM AREA
Divergent thinking
Recording data
Communication of ideas
Application of knowledge
Intellectual and motor skills
Social skills
Divergent thinking
IDENTIFICATION OF CONTROL FACTORS
Convergent thinking
Imposition of control factors
Convergent thinking
SPECIFICATION
Foundation work through 'soft' materials (i.e. card, clay, etc). Production of models
JUDGMENTS AND DECISIONS
Consolidations of workable solutions towards realization
ASSESSMENT OF GOAL ACHIEVEMENT