The effect of training for Field-independence on Formal Operations; the consequences for general ability and the effectiveness of developing an associated meta-cognitive language in combination with the training procedures.

by

John Newland Collings.

Submitted in part fulfilment for PhD
of the COUNCIL for NATIONAL ACADEMIC AWARDS

Sponsoring establishment:

College of Saint Paul and Saint Mary, Cheltenham.

Collaborating establishment:

Tewkesbury School, Tewkesbury.

Submitted: October 1987.

The effect of training for Field-independence on Formal Operations; the consequences for general ability and the effectiveness of developing an associated meta-cognitive language in combination with the training procedures.

ABSTRACT.

After conducting a number of pilot studies pre- and post-tests were given to three experimental classes of 11 to 13 year old early adolescents, one taken by Collings, and the two others by an inexperienced teacher. With one class the latter used materials designed to develop Field-independence only, with the other the teacher followed a similar pattern to Collings who incorporated a meta-cognitive aspect by encouraging students to analyse their own thinking strategies and to 'bridge' between the Field-independence lessons and the contexts of science. There were two control classes, and the overall period of the intervention was one school year with about 20% of the science teaching time used for the intervention. The tests used were the Group Embedded Figures Test (GEFT) for Field-independence, and Volume and Heaviness (SRTII), NFER (1979) for Piagetian operations. In the pre- post-test comparisons between experimental and control groups all the differences between the differences were statistically significant. Collings' own class showed an effect-size of 1.53 σ on GEFT over the controls, and 0.92 σ on SRTII. The inexperienced teacher's class with Field-independence training only, showed an effect-size of 1.09 σ on GEFT and 0.36 on SRTII whereas his class with meta cognition added showed an effect-size of 1.13 σ on GEFT, and 0.63 σ on SRTII. There was no statistical difference between the 1.09 and 1.13 σ on GEFT and this inferred that the Field-independence materials were fairly robust to teacher effects. The difference between 0.36 and 0.68 σ on SRTII was significantly different, and this was interpreted as showing that the meta-cognitive aspect assisted transfer of training to Formal Operations.

CONTENTS.

Chapter 1: Introduction.

The experimenter was a science teacher in an 11-18 rural comprehensive school. The performance of many pupils seemed to indicate that they lacked the ability to think sufficiently scientifically to cope with the science curriculum. During the last two years of compulsory schooling, i.e., 14-16, possibly due to pressures of examination syllabuses, staff did not seem to have time to develop scientific thinking which rendered important parts of courses inaccessible to many pupils. The experimenter decided that help should be given in the development of scientific thinking, and that such a scheme should begin in the first years of secondary schooling to enable pupils to approach problem solving more efficiently in the later years. A useful skill regardless of whether or not they would attempt science examinations.

The school used 'Science Reasoning Tasks' (NFER 1979), which are based on Piaget's developmental stages, as a means of assessing pupils' scientific ability. The experimenter had administered such tests before and noted that some pupils could not interpret the basic principles in the problems they were trying to solve. Working in ordinary classroom situations with data similar to that in the 'Science Reasoning Tasks', the experimenter also noted that pupils could find correct solutions if they were prompted to isolate the significant variables within a problem. It therefore seemed that success depended not on the mental capacity to cope with the problem, but that they were being hampered by being unable to identify the relevant variables within a task. Danner and Day (1977) found that prompting subjects to isolate relevant variables helped them to perform at Piaget's highest level that of Formal Operations. In their study they identified the lack of Field-independence as being particularly significant in identifying pupils who needed help in isolating the relevant factors in a problem. Reviewing the literature indicated there may be two aspects to Field-independence; 1) perceptual and 2) cognitive restructuring. A literature search revealed only one reference to training in the perceptual aspect of Field-independence, the outcome of which was unsuccessful and also that no one appeared to have attempted to develop the cognitive restructuring aspect of Field-independence. Cognitive restructuring of information seemed an obvious prerequisite to being able to perceive and manipulate variables in a Formal Operational task, and therefore, any increase in this contributory skill should have developed a higher level of Formal Operational thought. This suggested to the experimenter that if the cognitive restructuring aspect of Field-independence could be developed it should in turn help the development of scientific thinking. These ideas were formalized as described in the outline below.

Piaget's model of cognitive development has been widely accepted. The highest level, that of Formal Operations, is implicit in 'scientific method' and science curricula, a sophisticated approach that approximately only thirty percent of the population ever reach (Shayer, 1980). Developing Formal Operations seemed therefore to be a valuable contribution to education in general and science teaching in particular. Most attempts at training had aimed at developing specific Formal Operational skills and had had limited success. A different approach was indicated. It had been shown that Formal Operations was positively correlated to the cognitive style of Field-independence (Neimark, 1981; Stone & Day, 1980).

Field-independence is made up of two parts;

a) perceptual

b) cognitive restructuring.

Training in the perceptual aspect had been tried and shown to be unsuccessful (Morell, 1976). The isolation of variables in a Formal Operational task seemed to require similar abilities as the cognitive restructuring aspect of Field-independence, therefore, development of this aspect of Field-independence should develop some of the skills necessary to enable pupils to think at a Formal Operational level, diagram 1-1.

DIAGRAM 1-1: FLOW CHART OF BASIC IDEAS.

Scientific thinking requires Formal Operations

Formal Operations is correlated to Field-independence

Field-independence is made up of

Visuokinesthetic (perception)
unmodifiable

cognitive restructuring
possibly modifiable

Training materials to attempt to
modify the cognitive restructuring
aspect of Field-independence.

Increase in Field-independence and
Formal Operations measured by Group
Embedded Figures Test and Science
Reasoning Task II respectively.

The experimenter identified a number of skills that were necessary for subjects to develop Field-independence, these were;

a) disembedding the simple from the complex,

b) reorganising information to produce new patterns so breaking up a visual field and recreating it,

c) looking for hidden information systematically,

d) comparison, noting similarities and differences,

e) ignoring irrelevant and confusing material,

f) ignoring basic Gestalt theory of organising a visual field into a coherent whole rather than its constituent parts.

Training materials were developed by the experimenter to develop these skills. Experimental groups were given the training materials and the differences in performance in Field-independence and Formal Operations were tested and compared with controls.

Chapter 2: Literature Review.

This literature review describes the past research on which the thesis is based and covers the following areas;

1. *importance of Piaget and summary of his developmental stages,*
2. *principles and skills of Field-independence,*
3. *science education, Field-independence and Formal Operations,*
4. *the effect of training on, and the inter-relationship between Field-independence and Formal Operations,*
5. *summary and basis for thesis.*

1. IMPORTANCE OF PIAGET AND SUMMARY OF HIS DEVELOPMENTAL STAGES.

Many models of cognitive development have been suggested, e.g.; bi-dimensional learning (meaningfulness/mode) (Ausubel, 1968): a prescriptive theory of instruction (Bruner, 1966); mediated learning experience (Feuerstein, 1980); learning dependent on what has already been learnt (Gagné, 1967); general crystallized, general fluid and spatial ability (Horn & Catell, 1966); acceptance of lack of closure and multiple interacting systems (Lunzer, 1978): growth of logical thinking (Inhelder and Piaget, 1958). Although there has been some controversy over Piaget's ideas, see Modgil & Modgil (1982), Inhelder and Piaget's model (1958) and its subsequent development has been accepted by many as being particularly significant: see Archenhold et al. (1979), Head (1982), Jackson (1963), Lawson & Wollman (1976), Lovell (1979), Lovell & Shayer (1978), Modgil & Modgil (1976, 1982), Neimark (1975a, 1975b, 1979, 1981), NFER (1979), Selly (1981), Shayer (1979, 1980), Shayer & Adey (1981), Somerville (1974).

Lovell (1979. pp. 26-27) proposes eight areas of Piagetian research that are likely to have lasting value:

1) The sheer amount of factual knowledge established which shows at least some of the broad outlines of cognitive development. ....
2) His strong approval ... of the clinical method. ....
3) The extensive research that has been generated. ....
4) Piaget's emphasis on organization, for without this there can be no adaptation. ....
5) The position Piaget adopts in respect of the progressive construction of knowledge resulting from the interactions between subject and objects. If new knowledge is not progressively constructed by the individual himself, with the aid of teaching, action, observation, the use of material and/or language, and social interaction, as required, it remains imperfectly understood. ....
6) His perspective which maintains that knowledge is constructed out of the interaction between the person and reality for the cognitive structures involved in knowing are given neither in the object, nor in the person, but in the interaction between them. ....
7) The importance given to the role of cognitive conflict as a means of bringing about improved cognitive adaptation and hence a higher level of thinking. ....
8) .... The cognisance, or act of becoming conscious of an active scheme (i.e., of a repeatable and generalizable action), or of an internalized scheme for that matter, is a pre-requisite for

generalizations and for tackling new problems in which the same strategies are involved.

The work of Piaget and his co-workers is extensive, (Lovell, 1979, p. 13).

Piaget and his colleagues have published more than 40 books and a much larger number of articles. Further his work has generated an enormous amount of research... the compilation of Piagetian research by S. & C. Modgil (1976) is eight volumes long and contains 3500 references'.

Ibid, pp. 27-28.

'It is likely to be a long time before the lasting insight which Piaget has produced together with those established by others, can be brought together into a theory which subsumes or replaces his own. .... His theory will certainly have to be amended but it is too early yet to say what form the new one will take'.

Piaget's prime interest is in the development of how children come to and understand the physical world. He considers that there is always an underlying mental organization or structure to any action by a child. Piaget's theory of cognitive development suggests a series of stages. 'Stage' is used to describe a qualitative view of reality possessing describable features. Children will develop through these stages in a set order. The rate at which children go through these stages has been a matter of some debate especially the point at which children move into the final stage, Formal Operations. Movement from one stage to another is not necessarily a discrete jump. Children may well work mainly at one level and show occasional insights to the next higher level and slowly over time work more and more at the higher level. Children may develop further in one area of cognition more readily than another and will tend to show the most advanced thinking in areas, and with subject matter, with which they are most familiar (Wason & Johnson-Laird, 1972). The stage theory is descriptive rather than explanatory and, with further research, detailed expectations of what children should be able to do in science lessons at various stages have been evolved, e.g., Ennever & Harlen (1972) and Shayer & Adey (1981). Movement to the highest level, Formal Operations, does not take place in many school subjects. Most children work at the previous level of Concrete Operation all their adult lives. For all people, reality must be categorised and ordered through concrete operational schemata before Formal operational schemata can be applied. This means that even those who have access to Formal operational schemata only use them when concrete modelling has been found less than adequate for the purpose in question.

The stages that Piaget identified were;

1. period of sensori-motor intelligence 0- 2 years,
2. period of representative intelligence
   a) pre-operational stage 2- 7 years,
   b) concrete operational stage 7-11 years,
3. period of formal operational thought,
   a) organizational stage 11-15 years,
   b) achievement stage from 15 years.

A straight forward description of these stages appears in UNESCO (1980, p. 37). A more detailed description of what is expected of children in the classroom situation is described in Ennever & Harlen (1972) and Shayer & Adey (1981). Briefly, stage 1: the sensori-motor period is pre-school and restricted to cause and effect, permanence of objects, results of actions of others. Stage 2a to 2a/2b: early concrete operational period, develops the ability of representation, e.g., by language or other *mental images and the development of seriation and classification. Many 1st year secondary school pupils (11-12 years) are still at this stage of development. Stage 2b: mature concrete operations is the stage which most 1st year secondary pupils have reached. Concrete modelling with the schemata of classification, seriation, number and conservations are essentially descriptive of reality and not explanatory. Children can understand a process, consider its reverse and develop conservation of quantities. Stages 3a and 3b, the highest level, encompasses the general thinking skills that are necessary to think scientifically. The following description is quoted from UNESCO (1980, p.41):*

> *Thinking at the stage of Formal Operations, which usually starts in adolescence, makes use of the same mental operations that were available at the concrete operational stage, but now they are integrated into new structures of thought. .... He can draw conclusions from statements which are possibilities and not merely observations of reality; he can consider a number of possibilities simultaneously, and in combination with each other; he can deal with relations between relations, such as proportions. Where several variables must be considered, he is not restricted to dealing with them one at a time, as in the stage of concrete operations. He can experimentally or mentally cancel out the effect of all other factors, while systematically varying one to determine its effect.*

Formal modelling allows interpretation or explanation of events which have been effectively described with concrete modelling. It was these skills that this thesis was hoping to develop.

UNESCO (1980, p.44) states:

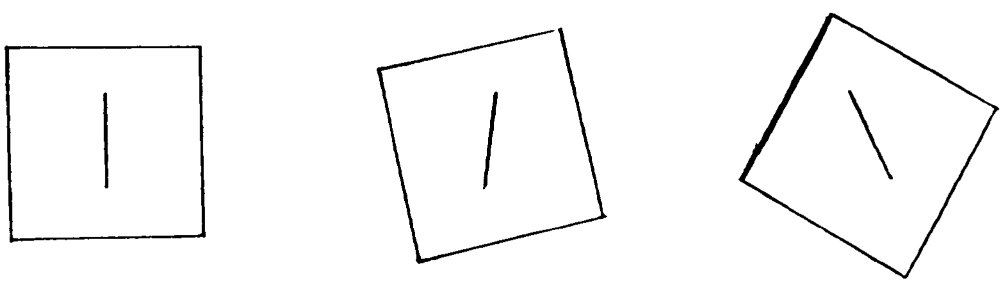
> *We still have a great deal to learn about children's thinking, but at this stage Piaget's theory seems more useful than any other for*

possible application to science education. No other theory about children's thinking is so comprehensive and has at least its major aspects so well-supported by experimental evidence from many parts of the world.

2. PRINCIPLES AND SKILLS OF FIELD-INDEPENDENCE.

The early work on Field-independence was conducted by H.A. Witkin in the late 1940's and early 1950's on perception of the upright in space. A detailed review is included in Witkin, Moore, Goodenough & Cox (1977). Witkin suggested that an object is perceived as upright by its relationship to other things around it and to the sensations felt within our bodies. To investigate the relationship of perception of the upright and physical cues Witkin developed the Rod and Frame Test. This comprised a luminous rod and frame in a darkened room: the rod and frame could be moved independently (see figure 2-1).

FIGURE 2-1: EXAMPLES OF INDEPENDENT MOVEMENT OF WITKIN'S 'ROD AND FRAME' TEST.



The subjects' task was to give instructions for the rod to be put upright independent of where the frame was positioned. Witkin identified two groups of people;

1) those that would tend to put the rod perpendicular to the frame, *2) those that saw the rod as independent of the frame and put it upright in relation to the rest of the surroundings even though these could not be seen.*

The former were called Field-dependent and the latter Field-independent, with a continuum in-between. Witkin also found a positive correlation between the laboratory task above and the pencil and paper task of finding a simple figure embedded in a more complex one: "... we come out with a qualitative indicator of the extent to which the surrounding organized field has influenced the person's perception of an item within it". (Witkin et al., 1977, p.5). In the former situation the subject's score is the amount of tilt of rod or body, in degrees, when these items are reported to be straight. In the embedded figures situation the score is the time taken to locate the simple figure in the complex design. Witkin et al. (1977, pp. 6-7) state:

> *the common denominator underlying individual differences in performance in these various tasks is the extent to which the person perceives part of a field as discrete from the surrounding field as a whole, rather than embedded in the field; or the extent to which the organization of the prevailing field determines perception of its components; or, to put it in everyday terminology, the extent to which the person perceives analytically.*

Witkin et al. (1977, p.7) go on to suggest that people who tend to be Field-dependent experience difficulty with any problem that requires "taking a critical element out of the context in which it was presented and restructuring the problem material so that the item is now used in a different context". By definition this is a Formal Operational act. If Field-independence could be developed this would enhance Formal operational development. Witkin et al. (1977, p.15) suggested:

> *A third characteristic of cognitive style is that they are stable over time. This does not imply that they are unchangeable; indeed some may be easily altered.*
>
> *Ibid p. 25 ... because the material to be learned is not clearly organized, the Field-dependent student may be at a disadvantage. Field-dependent students may need more explicit instruction in problem solving strategies.*

This suggested that although cognitive styles like Field-dependence/independence are stable over time they may be modifiable, and although Field-dependent subjects found difficulty in solving problems where the information was not well organized, they may be able to solve those problems if prompted to organize the information first. It was the strong parallels between the transfer of Concrete operations to Formal operations, requiring that reality must be categorised and ordered through concrete schemata before Formal operational schemata can be applied, and the lack of ability of Field-dependent subjects to order a confusing field on which to apply Formal operational schemata that formed the basis for this thesis. If Field-dependent subjects lack the skill to organise and extract significant information from a confusing field of information it would be unlikely they would be able to develop the organizational ability as a pre-requisite to thinking Formal Operationally. It is contended that some subjects cannot develop Formal operations not because they lack the mental capacity to operate at the Formal operational level but because they lack the Field-independent skill of extracting relevant material from a confusing field of information on which to operate Formal operational schemata. Some evidence for this was indicated by Danner & Day (1977) where subjects prompted with the relevant variables were able to solve Formal operational problems where previously they had not.

Development of the principles of Field-dependence/independence by Linn & Kyllonen (1981) and Linn & Swiney (1981), discussed in the next section, separated two areas of Field-independence, perception of the upright (the visuokinesthetic) and the isolating of simple factors from a more complex field (cognitive restructuring). Morell (1976) tried to develop the perception of the upright using a portable Rod and Frame Test and was unsuccessful. The experimenter could not find any reference to specific training in the cognitive restructuring aspect of Field-independence and hypothesised that training in this aspect may have a better chance of success than training in the visuokinesthetic aspect.

The experimenter identified, mainly from three papers Witkin (1962), Witkin, Goodenough & Karp (1967) and Witkin, Moore, Goodenough & Cox (1977), aspects of Field-independence that could possibly be trained. These were;

1) disembedding the simple from the complex,
2) reorganising information to produce new patterns so breaking up a visual field,
3) looking for hidden information systematically,
4) comparison: noting differences and similarities,
5) ignoring irrelevant and confusing material,
6) ignoring basic Gestalt theory of organising visual field into a coherent whole rather than its constituent parts.

Training materials based on these ideas were used in three studies and are discussed in detail in appendix 3 which also includes the rationale on which they were based and the particular aspect of the above they were trying to develop.

3. SCIENCE EDUCATION, FIELD INDEPENDENCE AND FORMAL OPERATIONS.

From the previous section it is contended that Field-independence is necessary to isolate variables to complete a Formal Operational task and the development of Field-independence has been given little regard. While it was the aim of the work reported in this thesis to develop Formal Operations, the importance of Field-independence in own right as well as its contribution to Formal Operations should not be underestimated.
Piaget's ideas have been used in several science programmes, e.g., Science 5-13 in England, the Science Curriculum Improvement Study in America and the Australian Science Education Project. For example, Science 5-13 is a series of source materials, each of the books covers a particular topic and is directed at specific Piagetian levels. Each book describes the type of investigation that could be carried out at its particular level and the particular skills and abilities a child should exhibit to succeed at that Piagetian level.
Analysis of the science curricula designed for secondary school pupils, (Shayer, 1972, 1974, 1978a, 1978b; Shayer & Adey, 1981) showed that much of the content requires Formal Operations. Shayer (1978a and 1978b) showed that Nuffield Combined Science, a course much used in British secondary schools, requires a high level of Piagetian demand if pupils are to see logic and coherence in the course. He claimed: (Shayer, 1980) "It has been shown that attainment of understanding in science is heavily dependent on the level of development of the pupil, as measured in Piagetian terms". Flavell (1963) describes Piaget's Formal Operational

stage as: "an orientation towards organizing data (combinatorial analysis), towards isolation and control of variables, towards the hypothetical, and towards logical justification and proof" (p. 211). These are the corner stones of the attitudes of science beyond observation, description, recording and recall.

That Formal Operations and Field-independence are implicit in much of science education is shown by the following aims for science education listed by various bodies.

1. Assessment of performance Unit (1984); Science at 11. (p. 9).

   3) Observation: making and interpreting investigations.

   4) Interpretation and application; Interpreting present information. Applying science concepts to make sense of new information.

   5) Planning of investigations.

   6) Performance of investigations

2. Assessment of performance Unit (1986; Planning science investigations at 11).

   The publication is directed to the identification, controlling and manipulation of variables.

3. Association for Science Education (1981, p. 11).

   a) the acquisition of a knowledge and understanding of a range of scientific concepts, generalizations, principles and laws through the systematic study and experience of the body of knowledge called science.

   b) The utilization of scientific knowledge and processes in the pursuit of further knowledge and deeper understanding, and the development of an ability to function autonomously in an area of science studies to *solve practical problems and to communicate that experience to others.*

c) The attainment of a perspective or way of looking at the world together with some understanding of how it complements and contrasts with other perspectives or ways of organizing knowledge and enquiry.

4. *Her Majesties Government Department of Education and Science (1981) 'The school curriculum'. (paragraph 47b).*

Too many 16 plus examinations test mainly the candidates' powers of recall, rather than testing sufficiently their understanding or their ability to think and work scientifically.

(Ibid paragraph 38).

Children should be given more opportunities for work which progressively develops their knowledge; it is equally important to introduce them to the skills and processes of science including observation, experiment and prediction.

5. *Her Majesties Government Department of Education and Science (1982) 'Science education in schools'. (p. 1).*

Moreover, the effectiveness of the broad curriculum which should now be offered to every pupil is enhanced by the inclusion of science. The content of science enriches other subjects, and is in turn enriched by them. Other subjects too foster the skill, and the approach to learning and reasoning, inherent in scientific method: science when it is well taught, makes a special contribution to their development.

6. *Her Majesties Government Department of Education and Science (1983) 'Curriculum 11-16', 'Towards a statement of entitlement'. (p. 29).*

> *Observational and visual skills the ability to observe accurately the ability to record distributions patterns and relationships, using scale, perspective, shape and colour and the ability to interpret observations.*

(Ibid p. 30).

> *Problem solving and creative skills. .... the ability to diagnose the features of problems the ability to; form hypotheses, design an experiment to test then evaluate their results, the ability to draw on relevant ideas and use materials inventively.*

7. *Her Majesties Government Department of Education and Science (1985a) 'The curriculum from 5-16' (p.29 paragraph 71).*

> *Scientific: ... science as a process of enquiry. These include observing selection from the observations of whatever is important, forming an hypothesis, devising and conducting experiments, communication in oral and symbolic forms and applying knowledge and understanding gained to new situations.*

(Ibid p. 72)

> *They should look for relationships or patterns and try to explain them. They should be encouraged to seek alternative explanations, to select those that seem most probable and test them by experiment.*

8. *Her Majesties Government Department of Education and Science (1985b) 'Science 5-13: A statement of policy' (p.3 paragraph 11).*

The essential characteristic of education in science is that it introduces pupils to the methods of science. So that scientific competence can be developed to the full, the courses provided should therefore give pupils, at all stages, appropriate opportunities to:

make observations;

select observations relevant to their investigations for further study;

seek and identify patterns and relate these to patterns perceived earlier;

suggest and evaluate explanations of the patterns;

design and carry out experiments, including appropriate forms of measurement, to test suggested explanations for the patterns of observations;

9. *Her Majesties Inspectorate (1978, p. 194).*

Criteria for the assessment of performance.

a) *Are the pupils observant? That is to say, do they see all that there is to see or do they rely on being told what to see?*
b) *Do they select from their observations those which have a bearing on the problem before them?*
c) *Do they look for patterns in what they observe and are they able to relate the current observations to others they have made earlier?*
d) *Do they seek to explain the patterns? If they can offer more than one explanation, do they attempt to rank them in order of plausibility?*

e) Do they have an acceptable level of practical skills in the efficient and safe handling of equipment.

f) Can they devise, or contribute to the devising of, experiments which will put to the test the explanation they suggest for the patterns of observations? Are they prepared to reconsider an explanation in the light of new evidence?

g) Do they possess the verbal and mathematical skills to allow them to interact adequately with classmates, with their teacher and with written and other material to which their attention is directed?

h) Do they respond to a novel situation by recalling and applying facts and generalizations previously learnt? Do they do this when the new situation is outside the immediate content of the school science course? That is to say, do they see the relevance of what they have learnt in the science lessons to situations outside the laboratory.

10. The Royal Society (1982, p. 4 paragraph 0.11).

Scientific knowledge is gained in many different ways. Some are highly complex and sophisticated, other like observing, describing, counting, measuring, tabluating and classifying are skills of which there are many examples in everday life. The same can be said of scientific prodedures such as generalizing, formulating and testing hypotheses and predictions ... There is therefore nothing mysterious about the 'scientific method' or about science itself. Science, however, does have a further fundamental attribute: like any other knowledge, it can be used, and in a very powerful way not only to help ourunderstanding of natural phenomena, but also to control and exploit them.

These bodies either state or imply that observation, selection of relevant variables, then, the planning and execution of an experiment that requires control of those variables, are necessary to carry out scientific method. To be able to seek relationships between variables, i.e., to work Formal Operationally it was first necessary to identify the variables. It is the contention of this thesis that without Field-independent skills it is unlikely that a subject would be able to think Formal Operationally because the subject could not identify the significant variables within a problem. Developing Field-independence should not only give pupils a useful skill in its own right but might also help to develop their Formal operational ability.

The aims listed above demonstrate that Field-independence and a Formal Operational level of thought are necessary for any child to succeed in science beyond the level of observation, recording and recall. Observation, recording and recall are important aspects of science but they hardly represent scientific thinking and the intellectual rigours of what is normally associated with science. Selly (1981) suggested that pupils who lack formal operations would be unable to;

a) develop systematic analysis of problems,

b) suggest possible solutions to problems,

c) understand reliability of evidence,

d) develop awareness of errors, degrees of confidence,

e) develop scientific scepticism and detect bias,

f) appreciate the difference between opinion and fact,

g) develop the ability to test hypotheses.

It can be seen therefore that Formal Operations is not only necessary to develop scientific thinking but also to use many of the more sophisticated levels of thought used in everyday life. Shayer, 1980, p. 723, "It has been shown that attainment of understanding in science is heavily dependent on the level of development of the pupil as measured in Piagetian terms. It has also been shown that the developmental range of children proceeding through secondary education is far wider than previously thought".

4. THE EFFECT OF TRAINING ON, AND THE INTER-RELATIONSHIP BETWEEN FIELD-INDEPENDENCE AND FORMAL OPERATIONS.

Training in Formal Operations has been demonstrated, see Bredderman (1973), Kuhn & Brannock (1977), Lawson & Wollman (1976), Lawson, Blake & Norland (1975), Levine & Linn (1977), Rosenthal (1979), Shayer & Wylam (1978), Linn & Thier (1975), Siegler, Liebert & Liebert (1973). The main problem seemed to be generalizing the strategy beyond the context in which it was learnt. The studies that showed the most successful development of Formal operations were those that had either much consolidation, (Linn, 1980, Linn & Thier, 1975) or where there had been training in identifying variables, (Danner & Day, 1977, Shayer & Wylam, 1984).

Case (1974), Lawson (1976), Linn (1978), Neimark (1975b, 1981), Saarni (1973), Stabler (1983) and Stone & Day (1980) had suggested that the ability to think Formal Operationally was positively correlated to the cognitive style of Field-independence. Linn & Swiney (1981) found that Field-dependence/independence was significant in clarifying the individual differences in Formal Operational thought. Danner & Day (1977) showed that some students could perform at a Formal Operational level after controlled prompting in similar tasks. Stone & Day (1980) reported four factors to account for the differences between spontaneous users of Formal operations and the latent users who needed prompting. The factors were ambiguity of instructions, selective attention, short term memory and Field-independence. They found that Field-independence was most successful at differentiating between spontaneous and latent users of Formal Operations, i.e., Field-independent subjects developed Formal Operations more easily than Field-dependent. Case (1974) and Linn (1978) trained children in Formal Operational thinking. Their training procedures were most successful with subjects who were demonstrably Field-independent. Field-independence was not only correlated with Formal Operations, Goodenough & Karp (1961), Flexer & Roberge (1980) had also shown that overcoming embeddedness (the crucial part of Field-independence) was a common factor in many tests of intelligence. Elkind & Scott (1962) showed that perceiving ambiguous figures, i.e., disembedding, varies with IQ. Keating (1975) showed that there was a high correlation between IQ and the onset of Formal Operations. Cantu-Salinas (1978) showed that Field-dependence/independence was an important factor in the development of science concept attainment in students. Witkin, Moore, Goodenough & Cox (1977) cited Field-independence as a vital part of problem solving and symbolic representation, i.e., 'taking some critical element out of the context in which it is presented and restructuring the problem material so that it is used in a different context'. Witkin, Goodenough & Karp (1967) suggested that development of Field-independence levels off at 14-17 and therefore any training if it was to be successful must take place during the developmental period, i.e., primary school or early secondary. Formal Operations was unlikely to develop during a pupil's time at *primary school (except in a minority of subjects) but development of Field-independence could take place in primary school or in the first two or three years of secondary education. This thesis suggests that development of Field-independent skills would not only give subjects greater Field-independent proficiency but that it would also develop their Formal Operational ability.*

Linn & Kyllonen (1981) suggested that there had been much confusion over exactly what was being measured in Field-dependence/independence. Studies often used different tests to assess Field-dependence/independence, e.g., Weschler Intelligence Scale for Children (WISC) block Embedded Figures Test, Group Embedded Figures Test or the Rod and Frame Test. Witkin's original concept was measured using the Rod and Frame Test (see Witkin (1962)). Linn & Kyllonen (1981) indicated that although Witkin had found correlations between the Rod and Frame T est and Embedded Figures Test and had assumed that the Embedded Figures Test also measured Field-dependence/independence, subsequently Witkin, Goodenough & Cox (1977) have suggested that the Rod and Frame Test and the Embedded Figures Test do not overlap when used interchangeably and that each test measures a different aspect of Field-dependence/independence. The Rod and Frame Test measuring perceptual ability and the Embedded Figures Test cognitive restructuring ability. Vernon (1972) suggested that Field-dependence/independence is composed of the visuokinesthetic and, a combination of general intelligence and spatial ability. Nebelkopf & Dreyer (1970) found high correlations between Field-independence and perceptual restructuring. Linn and Kyllonen (1981) suggest that in the past, experiments using Rod and Frame Tests as a Field-dependence/independence measure, measured the perceptive aspect of Field-dependence/independence. When spatial tests *such as Embedded Figures Test and Hidden Figures Tests were used the cognitive restructuring aspect was measured. In an attempt to clarify the confusion Linn & Kyllonen (1981) carried out a correlational analysis on 34 general ability tests 12 of which were concerned with Field-dependence/independence. They identified two aspects of Field-dependence/independence: 1) familiar field; correlating with perceptual tests and 2) general fluid visualization correlating with such tests as Embedded Figures Test, Hidden Figures Test and Raven Advanced Matrices. It therefore seemed likely that the earlier Formal Operations//Field-dependence/independence correlation of Case, Linn, Lawson etc., could have been correlation between different aspects of Field-dependence/independence depending on which test was used to determine Field-dependence/independence. Linn & Kyllonen (1981) attempted to correlate their Field-dependence/independence to the general ability model of Horn & Cattell (1966) modified by Snow et al. (1977). Snow's model demonstrated that ability can be divided into general crystallized ability, i.e., over-learnt material, e.g., vocabulary, and general fluid visualization defined by tests of mental manipulation of figural and non-figural material. Linn & Kyllonen (1981) then used the model and elaborated it to include their two aspects of Field-dependence/independence, i.e., cognitive restructuring and visuokinesthetic. They found that the crystallized ability was separable as a distinct item. They could not however separate general fluid visualization from the restructuring aspect of Field-dependence/independence. A third dimension was then identified which they called familiar field, a combination of perception of the upright and an aspect defined by a picture completion subtest. Familiar field was hypothesized to measure strategy selection in familiar situations. This produced a three dimensional model of;*

general crystallized ability, general fluid visualization (which encompassed the restructuring aspect of Field-dependence/independence) and familiar field. Linn and Swiney (1981) then investigated the correlation between the aspects of this three dimensional model and Formal Operations. They found that only 12% of Formal Operations was not accounted for by a combination of the three dimensional model (see diagram 2-2). They also demonstrated a strong link between formal operations and the cognitive restructuring ability of the general fluid visualization dimension of Field-dependence/independence especially when combined with general crystallized ability. The cognitive restructuring of the general fluid visualization part of Field-independence was implicated in such a wide range of cognitive abilities, in particular possible implications in the developing of Formal Operations. Thus training in the cognitive restructuring part of Field-independence seemed to be an important skill to develop.

Training in the cognitive restructuring aspect of Field-independence would constitute practice in looking at information, patterns, etc., and trying to identify differences, impose patterns or produce new patterns from existing ones, i.e., any activity that involved careful scrutiny of structure and/or restructuring of structure. This was in general agreement with Danner & Day (1977) and Shayer and Wylam (1984), Witkin, Moore, Goodenough & Cox (1977), i.e., assisting students to identify variables and manipulate them. The more practice students had at restructuring information the more easily they were going to be able to identify variables in novel situations. If the aims of the various bodies concerned with science education are re-read it will be seen that the development of Field-independence is advantageous to science education

DIAGRAM 2-2: REPRESENTATION OF LINN & KYLLONEN'S GENERAL ABILITY MODEL.

Horn and Cattell's model

General crystallized *General fluid visualization* *Spatial*

Modified by Snow to;

General crystallized *General fluid visualization* *Spatial*

General crystallized *General fluid visualization (including Spatial)*

Linn & Kyllonen added the two aspects of Field-dependence/independence ie: Cognitive restructuring and Perception of Upright (the visuokinesthetic). They found the cognitive restructuring aspect of Field-dependence/independence overlapped with General fluid visualization. With the addition of a picture completion test, perception of the upright and became familiar field

General crystallized *General fluid visualization* *Spatial*

General crystallized *General fluid visualization (including Spatial)*

General crystallized *Cognitive restructuring (including General fluid visualization (including Spatial))* *Familiar field (including perception of upright visuokinesthetic] and picture completion*

Linn & Kyllonen then added Formal Operations and found that all but 12% of Formal Operations was accounted from by a combination of General crystallized, cognitive restructuring and familiar field.

General crystallized *General fluid visualization* *Spatial*

General crystallized *General fluid visualization (including Spatial)*

General crystallized *Cognitive restructuring (including General fluid visualization (including Spatial))* *Familiar field (including perception of upright [visuokinesthetic] and picture completion.*

88% Formal operations 12% other factors in its own right, i.e., developing more careful observation, detecting patterns etc. If development of Field-independence could have helped to develop Formal Operations it would have clearly demonstrated that training in Field-independence should be an integral part of general education and science education in particular.

On the basis of these ideas it was reasonable to hypothesize that if Field-independence was correlated with Formal Operations and the restructuring aspect of Field-independence could be influenced by training, then modifying Field-independence might produce an increase in Formal Operations. Figure 1-1 summarizes these ideas.

To test whether developing Field-independence had an effect on Formal Operations it was necessary to develop a training programme that developed the cognitive restructuring aspect of Field-independence but could not be construed as direct training of Formal Operations. A detailed description and rationale behind all the materials developed for all three studies is given in appendix 3. In brief, initially eight different activities were compiled to develop the skills of careful comparison, reorganization and restructuring of information, isolation of the particular from the general and disembedding of confounding or overlapping information: i.e., the Field-independent skills discussed earlier. For ease of classroom organization four of these were computer 'games' and four practical written items. Once the computer programs were written and other materials produced they were piloted with eight pupils who did not take part in subsequent work. Work was conducted in the summer term of 1983 to try out: 1) the administration of the test used and 2) materials for acceptability and effectiveness. The details of this pilot study are given in the next chapter.

5. SUMMARY AND BASIS FOR THESIS.

Field-dependence/independence is a cognitive style that identifies a subjects' ability to identify the particular from the general. Control of variables is a factor in Formal Operational schemata and so if subjects are not Field-independent then they are unlikely to be able to isolate the significant variables in a problem even if they have the mental capacity to manipulate those variables in a Formal Operational way. As only about 30% of 15/16 year olds ever reach Formal Operations, (Head, 1982), Lawson & Renner, 1975), Lovell and Shayer, 1978), Sayre & Ball, 1975), Shayer, 1980), Shayer & Wylam, 1978) much of science teaching is conceptually too difficult for many pupils. Therefore, aiding pupils to develop Field-independence and consequentially Formal Operations is an important adjunct not only to science education but also to the pupils' personal development. Formal Operational thought is not just of use in science, although it may exhibit its most obvious manifestation there, it is a powerful cognitive tool applicable to many other spheres of learning and professional practice especially at their higher levels. If Formal operational development can be enhanced by training in Field-independence then this will also develop such skills as careful comparison, reorganization and restructuring of information, isolation of the particular from the general and disembedding of confounding or overlapping information. These field-independent skills are important in their own right.

Chapter 3: Pilot Study.

The literature review established that if reality requires categorization and ordering of reality through use of Concrete operational schemata before Formal operational schemata can be used, it is necessary for the objects comprising reality to be comprehended as discrete entities, a Field-independent skill. This suggested an explanation of the correlation between Formal operations and Field-independence. If subjects were not Field-independent then they were most unlikely to view the individual components in a Formal-operational task as separate items whose relationships could be investigated in some way. This did not necessarily mean that subjects lacked the mental ability to relate these items Formal operationally but that they did not have the Field-independent skills to enable separation of components of the problem and identify them as discrete and capable of investigation. Support for this contention came from Danner & Day (1977) and Shayer & Wylam (1984) where prompting subjects with the significant items to be operated on, produced significant increases in their Formal operational ability. The experimenter was led to the conclusion that increasing Field-independent ability would enable some subjects to perform at a Formal operational level where previously they had not. This would not apply to all pupils; some may well be Field-independent and still not be able to perform at a Formal operational level. The research was aimed at subjects who could not perform Formal operationally because they could not identify the significant items within a problem in order to solve it. If training was given in order to develop Field-independence, and a significant number of subjects over controls then demonstrated the ability to solve Formal operational problems, the hypothesis would be supported.

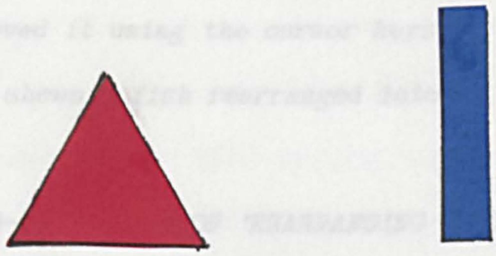
A set of training materials was developed by the experimenter in an attempt to give pupils the opportunity to practise skills identified above as associated with the cognitive restructuring aspect of Field-independence, i.e.;

1) *disembedding the simple from the complex,*
2) *reorganising information to produce new patterns so breaking up a visual field,*
3) *looking for hidden information systematically,*
4) *comparison, noting differences and similarities,*
5) *ignoring irrelevant and confusing material,*
6) *ignoring basic Gestalt theory of organising visual field into a coherent whole rather than its constituent parts.*

The materials consisted of five computer programs and five written exercises. The written exercises were; random pictures, matching rows, rearranging, embedded figures and eight words, the computer programs were the same but with interaction on the screen. Appendix 3 gives detailed descriptions of all the materials used in all the studies but a brief description of the ones used in this study follows.

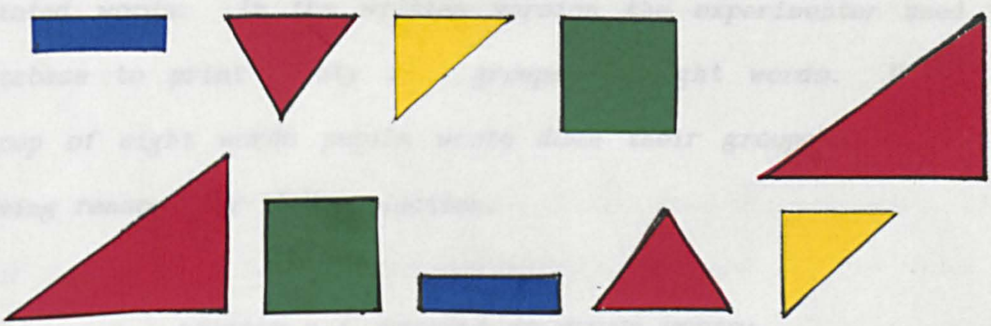
Random pictures: two pictures were displayed side by side. The task was to identify whether they differed in shape, size and colour. The presentation gradually introduced up to four shapes, three sizes and seven colours. The computer version progressively reduced the time of each display from seven seconds to one second, told pupils whether they had been correct or not and gave them a score after each block of ten questions. The written version was a set of cards with the shapes on them and a sheet on which to record the answers for each card.

DIAGRAM 3-1: EXAMPLE OF 'RANDOM PICTURES'.



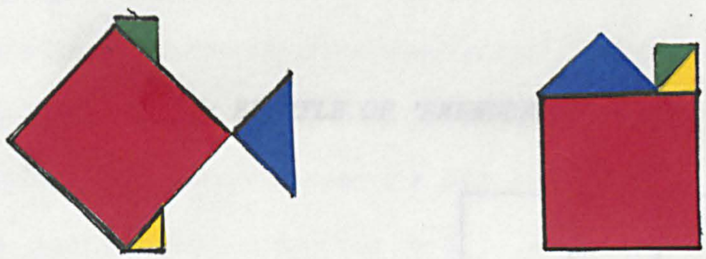
Matching rows: *two rows of five shapes were presented each of which was randomly selected from six colours, four sizes and nine shapes. The second row was the same as the first except the order was randomly rearranged and there was also one chance in two of a figure appearing in it that did not appear in the upper row. A different figure in the bottom row produced a mismatch. The computer version told the pupils whether their choice was correct or not. The written version was a set of cards and answer sheet as above.*

DIAGRAM 3-2: EXAMPLE OF 'MATCHING ROWS'.



Rearranging pictures: *a picture was presented made of up to six different shapes each of a different colour. The pupils then rearranged the shapes to form a new picture by moving them. The written version required pupils to draw the original shape and their* new one. In the computer version the pupils identified each shape by its colour then moved it using the cursor keys to make a new picture. The example below shows a fish rearranged into a house.

DIAGRAM 3-3: EXAMPLE OF 'REARRANGING PICTURES'.



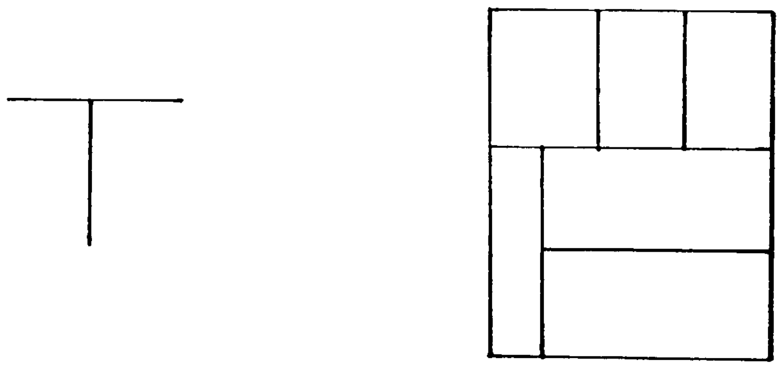
Eight Words: in the computer version eight words were presented randomly from a database of 130 words. The pupils' task was to group four of them together for some reason, e.g., number of letters, starting with the same letter, meaning etc. The whole group of eight words and the four selected words were printed as a record. At the end of the program the pupils were directed to the teacher with their printed words. In the written version the experimenter used the database to print twenty four groups of eight words. Using the group of eight words pupils wrote down their groups of four also giving reasons for their selection.

DIAGRAM 3-4: EXAMPLE OF 'EIGHT WORDS'.

Shadow	Doctor	Mug
Orange	School	Jelly
Jumbo	Orange	Photograph
Owl	Juice	Lighthouse
Hamburger	Balloon	Igloo
Ink	Mountain	Cheese
Dentist	Autumn	Magnet
Magnet	Lighthouse	Envelope

Embedded figures: two figures were presented. A simple figure and a more complex figure. The task was to find the simple figure in the more complex one. In the computer version of this task the simple figure was manipulated over the complex version using the cursor keys. The written version required the simple figure to be drawn on the more complex figure.

DIAGRAM 3-5: EXAMPLE OF 'EMBEDDED FIGURES'.



The pilot study was given to see whether the idea of training in Field-independence could be undertaken with any success and whether this training had any effect on Formal Operations.

The school had a nine stream entry: one of the nine classes was a slow-learning group, and the remaining eight classes were divided into two main blocks. Each block was subdivided into an upper and lower ability band of two classes. The selection for the groups was by Staff assessment, Science Reasoning Tasks II (NFER 1979) given in the first year in secondary school and VRQ given in the primary schools. The sampling frame was 53 second year pupils from the upper ability classes of the two main blocks. The 53 selected second year pupils were re-tested using Science Reasoning Task II and their Piagetian levels established. Any pupil who was not at the 2B level (concrete operational stage) was rejected. The reasoning behind this was that if any pupils were higher than 2B they had already reached the stage that the training was trying to develop, i.e., 3A early organizational stage of Formal Operational thought, and those less than 2B were not at a stage where they would benefit significantly from the training. The remaining number was seventeen. These pupils were then given the Group Embedded Figures Test, and eight were randomly chosen for the trial on the basis of their scores. The pupils were presented with a combination of science teaching and use of training materials for seven lessons, each of which comprised two thirty-five minute periods. The materials including the computer programs were created by the experimenter. The class of eight was split into four groups of two, designated 1a, 1b, 2a & 2b, and organised as follows;

Week 1
lesson 1

period 1	period 2
group 1a & 1b Science teaching	group 1a written materials group 1b computer materials
group 2a written materials group 2b computer materials	group 2a & 2b science teaching

Week 2
lesson 1

period 1	period 2
group 1a & 1b Science teaching	group 1b written materials group 1a computer materials
group 2b written materials group 2a computer materials	group 2a & 2b science teaching

A weekly pattern of written material in one lesson and computer material in the other was repeated for three and a half weeks. Each pupil received two half hour science sessions per week, plus one half hour using written material and one half hour using computer materials each week.

On the last session of the four week trial period the pupils were re-tested on Group Embedded Figures Test (GEFT), Science Reasoning Task II (SRTII) and were given a short questionnaire to assess acceptability of the materials.

RESULTS

TABLE 3-1: PRE/POST-TEST DATA FOR PILOT STUDY.

		pre test		post test		t-test and significance			
N		GEFT	SRTII	GEFT	SRTII	GEFT		SRTII	
						t	p	t	p
8	X	13.50	4.00	15.75	4.75	6.15	<0.0005	2.30	<0.01
8	σ	2.20	0.00	2.38	0.76				

The findings of the trial were;

1. Administration of the tests was straight forward but administration of Science Reasoning Task II needed rehearsing,
2. The pupils were bored repeating tests only four weeks apart,
3. The post tests were given too close to the end of term, i.e., the day before school closed,
4. The written materials seemed robust and required only minor changes.

5. Some modification of the computer programs was needed to make them more robust, less prone to accidental corruption and to give better presentation of diagrams.
6. There was enough material for eight pupils for four weeks but it became obvious that more materials were going to be needed.
7. The computer versions of activities called 'rearrange' and 'embedded figures' were too slow to be of much use.
8. The materials were enjoyed especially those using the computer.

DISCUSSION

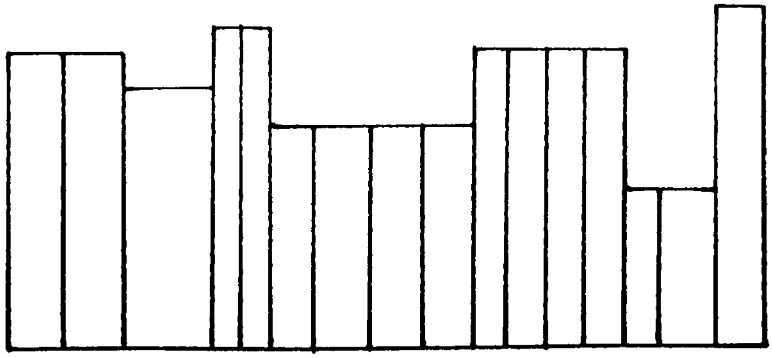
The figures in table 3-1 above showed that there were significant increases on GEFT & SRTII in three and a half hours of training, significant at $p<0.0005$ and $p<0.01$, respectively on a one tailed t-test. With these findings, although on small numbers, it was felt that there was sufficient evidence to proceed to a fuller study. The larger numbers and modification of the materials entailed more complex organization.

Chapter 4: 1st Feasibility Study

Some alterations to the materials were made before the feasibility study was undertaken. The computer versions of 'rearrange' and 'embedded figures' were removed; children found them boring because they were too slow. Both versions of 'eightwords' were removed for the same reason. Two new programs were included, one commercial program called 'pattern' and another written by the experimenter called 'shape in shape'. As the 'pattern' computer program could not easily be converted to a written task, 'wordsearches' were introduced as an extra written task. The 'wordsearches' were compiled using a computer program written by the experimenter using words the children encountered in their science lessons. A complete review of all the materials used and their rationale is given in appendix 3 but a brief description of the new materials used in this study follows.

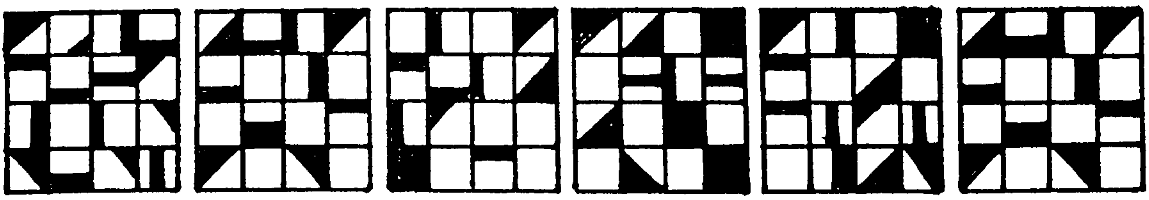
<u>Shape in shape:</u> pictures made up of outlines of squares, rectangles or triangles were presented. The pupils were asked how many of a particular shape appeared in the picture. The computer version blocked out each of the shapes and kept a tally on the screen.

FIGURE 4-1: EXAMPLE OF 'SHAPE IN SHAPE'.



<u>Patterns:</u> this was available as a computer program only. The program presented up to five grids, of up to sixteen squares each, depending on the level of difficulty selected. The squares had various parts blocked out. The task was to match a given extra grid with one of the existing five.

FIGURE 4-2: EXAMPLE OF 'PATTERNS'.



grid 1 grid 2 grid 3 grid 4 grid 5 match grid

<u>Word Searches:</u> these were 10 X 10 matrices of letters, within which words used in science teaching were hidden. The task was to identify these words by ringing them.

FIGURE 4-3: EXAMPLE OF A 'WORDSEARCH'.

R	A	D	I	C	L	E	O	K	C		I	I	H	C	K	T	H	J	Q	M
E	B	V	E	J	P	W	F	S	O		P	F	G	N	I	T	T	O	L	B
S	S	L	X	N	A	T	S	E	T		I	N	M	N	F	M	A	I	Z	E
P	O	Q	A	V	E	R	O	E	V		P	E	A	S	S	H	O	O	T	C
O	R	E	R	R	L	O	Y	D	L		E	R	O	O	T	Y	I	D	N	B
N	B	J	M	Z	U	P	R	S	E		T	R	Q	W	A	D	E	I	R	D
S	C	A	R	V	M	I	B	R	D		T	F	O	Z	R	H	T	N	V	U
E	L	G	H	P	U	S	M	K	O		E	R	O	R	C	X	K	E	K	S
N	Y	Z	P	G	L	M	E	G	N		G	J	U	I	H	W	V	V	O	O
M	I	C	R	O	P	Y	L	E	J		G	T	M	B	G	V	P	N	D	D

Once the alteration to the materials and administration had been solved a final study was carried out for the whole of the Spring term of 1984.

SAMPLE.

A whole year group of first years (11-12 years mixed comprehensive, N=270) formed the sampling frame. The children were tested in their Primary schools using 'Richmond tests' (Hieronymus, Lindquist & France, NFER 1975). These scores were used when the pupils first came into the school in September to assign pupils to mixed ability tutor groups. Sixteen children identified as slow learners by Primary school recommendation and tested as above, took no part in the experiment. For administrative convenience the school arranged the mixed ability tutor groups of children into two blocks. The first contained four tutor groups and the second five. The experimenter had no control over this process. The groups taking part in the study were selected randomly, the experimental group from one block and the control group from the other. An attempt was made to get experimental and control groups that reflected the same proportions of Formal operational levels as those in the sampling frame (this was a change from the trial where all pupils were 2B). To do so all 254 children were tested for Formal operations using Science Reasoning Task II. From this the proportions of pupils performing at the various Formal operational levels were determined and these figures used to find the numbers of pupils required at each Formal operational level for each of the groups. Pupils were chosen randomly from each level: the experimental group from one block and the control group from the other. The experimental and control groups were then tested for Field-dependence/independence using Group Embedded Figures Test. Tables 4-1 and 4-2 show the distributions after test mortality. A Kolgromov-Smirnov test was carried out to test for the significance of *the difference of distribution between the experimental and control groups on their Field-independence level, and Formal Operational level using the data in tables 4-1 and 4-2. The calculations are included in appendix 1.*

TABLE 4-1: THE DISTRIBUTION OF PRE TEST GROUP EMBEDDED FIGURES TEST SCORES IN 1ST FEASIBILITY STUDY SAMPLE.

		GEFT score distribution					
Group	N	0-2	3-5	6-8	9-11	12-14	15-17
Expt.	20	2	2	7	3	3	3
Control	21	3	4	7	3	3	1

TABLE 4-2: THE DISTRIBUTION OF PRE TEST SCIENCE REASONING TASK II SCORES IN 1ST FEASIBILITY STUDY SAMPLE.

		SRT II Distribution				
Group	N	2A	2AB	2B	2B3A	3A
Expt.	20	3	8	8	1	0
Control	21	5	3	8	5	0

The results of these calculations showed that there was no significant difference in the distribution of groups on Field-independence and Formal Operations as measured using Group Embedded Figures Test and Science Reasoning Task II respectively. It was not possible to select randomly two groups of pupils from the whole of the 1st year, so there may have been factors which were not controlled. The control group had normal science lessons with another member of staff and had no further contact with the experimenter until they were re-tested at the end of the training period of 12 weeks. No attempt was made to control for teacher variation.

METHOD

The pupils were timetabled for two 70 minute sessions per week. Taking five minutes to start a lesson and five minutes to clear up this left two one hour lessons per week. Each lesson was divided into three 20 minute sessions. Two of the sessions were for science teaching and one for the use of the training materials. Half the training materials required using a computer. As there were only two computers available not all the pupils could use the computers at the same time. It was therefore necessary to divide the pupils into three groups of eight and rotate them as follows:

	1st 20mins	2nd 20mins	3rd 20mins
group 1	Science	Science	Materials
group 2	Science	Materials	Science
group 3	Materials	Science	Science

As this would have meant group 2 were always at a disadvantage having their science split up i.e. science, materials, science, it was necessary to rotate the order each lesson so that any disruption was equitable. The following scheme was adopted.

	1st lesson	2nd lesson	3rd lesson
group 1	sci. sci. mat.	sci. mat. sci.	mat. sci. sci.
group 2	sci. mat. sci.	mat. sci. sci.	sci. sci. mat.
group 3	mat. sci. sci.	sci. sci. mat.	sci. mat. sci.

Each sci. (science) or mat. (materials) representing 20 mins in a lesson.

During the 20 minutes using the Field-Independence training materials each group of eight pupils was divided into two groups of four. One pair worked on one of the two computers whilst the other pair worked on some of the written materials. During the next training session the pupils who previously worked on the computer worked on the written materials and vice-versa. Although this process was complicated it was necessary to enable equitable exposure to the range of materials, and to disrupt the science teaching as little as possible. In one week it enabled each pupil to have eighty minutes science teaching; and forty minutes Field-independence training, comprising twenty minutes of individual work on written materials and twenty minutes working in pairs on a computer. The pupils were given a sheet showing their rotations so they could keep track of what they were doing lesson by lesson.

Once the twelve week training period was over the experimental and control groups were post-tested using Group Embedded Figures Test and Science Reasoning Task II.

The null hypotheses being tested were:

(i) that after training there would be no difference in mean scores between the Field-independence levels of the experimental group and the control group.

(ii) should the experimental group be significantly more Field-independent this would not be associated with an increase in Formal operational level measured by Science Reasoning Task II.

RESULTS.

TABLE 4-3: MEANS AND STANDARD DEVIATIONS FOR PRE AND POST TEST SCORES FOR 1ST FEASIBILITY STUDY ON GROUP EMBEDDED FIGURES TEST.

		Pre test		Post test		Difference pre-post test	
Group	N	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}_2-\bar{X}_1$	σ
Experiment	20	8.80	4.83	13.70	3.84	4.90	3.02
Control	21	7.09	4.10	8.76	5.49	1.67	3.75

TABLE 4-4: MEANS AND STANDARD DEVIATIONS FOR PRE AND POST TEST SCORES FOR 1ST FEASIBILITY STUDY ON SCIENCE REASONING TASK II.

		Pre test		Post test		Difference pre-post test	
Group	N	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}_2-\bar{X}_1$	σ
Experiment	20	2.35	0.81	3.35	0.75	1.00	0.55
Control	21	2.80	1.03	3.33	0.80	0.52	0.75

TABLE 4-5: t-VALUES BETWEEN EXPERIMENTAL AND CONTROL GROUPS ON THE DIFFERENCES BETWEEN MEAN PRE AND POST TEST SCORES IN 1ST FEASIBILITY STUDY.

Test	t
Group Embedded Figures Test	6.96
Science Reasoning Task II	4.84

To enable clear presentation of the results the use of 'effect sizes' and percentiles was employed. The effect size is a representation of the effect an intervention has over control expressed in standard deviation units. The formula used was: Difference in experimental group means -

Difference in control group means / Square root of the mean of the squares of the standard deviations of the groups. Hyde (1981) argues that reporting of data such as this should include effect sizes. The use of percentiles enabled the diagrammatic representation of the results as has become routine in some reporting, (Rosenthal, 1978 and Smith & Glass, 1977, 1981). Use of percentiles assumes the data is normally distributed. Two normal distribution curves are plotted on a base line graded in standard deviation units. The area under the experimental group distribution that is situated to the right of the mean of the control group distribution represents the proportion of the experimental group that were performing at a higher level than the mean of the control group. The percentile is a means of presenting that area as a percentage of the whole distribution. The conversion from standard deviation units to percentiles was achieved using the table in appendix 7.

TABLE 4-6: EFFECT SIZES AND PERCENTILES OF EXPT. OVER CONTROL GROUPS ON THE DIFFERENCES BETWEEN PRE AND POST TEST ON THE GROUP EMBEDDED TEST AND SCIENCE REASONING TASK II.

Test	Effect Size	Percentile
Group Embedded Figures Test	0.70	76th
Science Reasoning Task II	0.56	69th

FIGURE 4-4: SHADED AREA SHOWS 76% OF EXPERIMENTAL GROUP PUPILS ARE BETTER THAN THE MEAN OF CONTROL GROUP PUPILS ON THE GROUP EMBEDDED FIGURES TEST

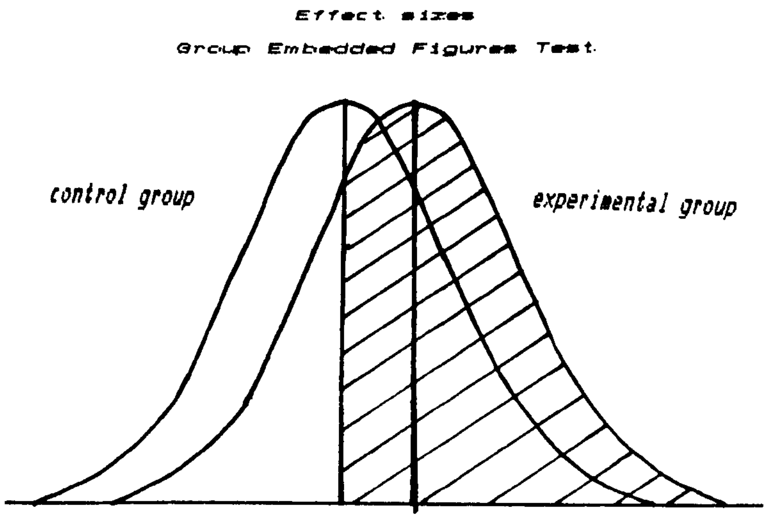
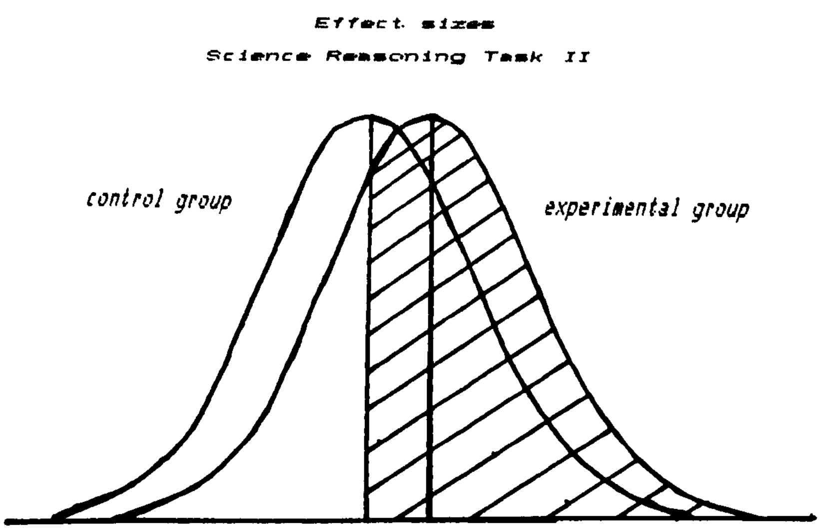


FIGURE 4-5: SHADED AREA SHOWS 69% OF EXPERIMENTAL GROUP PUPILS ARE BETTER THAN THE MEAN OF CONTROL GROUP PUPILS ON SCIENCE REASONING TASK II.



Test reliabilities of 0.82 for Group Embedded Figures Test and 0.78 for Science Reasoning Task II were included when calculating one tailed t-tests. The results of t-tests showed that there were significant differences in the scores of the experimental group over the control group in both the Group Embedded Figures Test and Science Reasoning Task II (see table 4-5 & 4-6 and figures 4-4 & 4-5). Using a one tailed t-test between unmatched experimental and control groups the differences between their pre- and post-test scores were significant at $p<0.0005$ for the Group Embedded Figures Test and $p<0.0005$ for Science Reasoning Task II. Using Effect sizes and the percentile table (appendix 7) figures 4-4 and 4-5 showed that in the case of Group Embedded Figures Test 75% of the experimental group were scoring higher than the mean of control group pupils and in the case of Science Reasoning Task II 69% of the experimental group were performing higher than the mean of control group pupils. Figures 4-4 and 4-5 are not accurate representations of the data, they are included as visual representation of the data as described above.

Using a t-test on the difference of the differences was more powerful than just testing for any significance of differences between the groups on pre test and subsequently on post-test. MacNemar (1962, p. 91 & 97) suggests that data such as this is suitable for a t-test on the difference of the differences and develops the following argument. Experimental and control groups may often change in the same direction as indeed happened in this case. The difference between the groups may rely on small z ratios, i.e., the ratio for a difference in means;

$$z = \frac{M1 - M2}{\sigma_{dm}}$$

He then argues that it is the net differences in any change that are important and the sampling errors in the difference should determine the significance of the results. Using the t-test formula for unmatched groups on the difference of the differences and including test reliability 0.82 for Group Embedded Figures test and 0.78 for Science Reasoning Task II the results were those quoted in table 4-5 above. To confirm that the results were as valid as this test showed, McNemar's test was also applied to find the significance of the difference between the differences using means and σ, for calculating the standard error of estimate. The data from tables 4-3 and 4-4 was used respectively as follows and test reliabilities as above;

Group Embedded Figures Test.

$$SE_{D_e} = \frac{3.02 \times \sqrt{(1-0.82)}}{\sqrt{20}} = 0.287$$

$$SE_{D_c} = \frac{3.75 \times \sqrt{(1-0.82)}}{\sqrt{21}} = 0.347$$

$$SE_{D_d} = \sqrt{0.287^2 + 0.347^2} = 0.450$$

$$t = \frac{4.90 - 1.67}{0.450} = 7.20$$

Science Reasoning Task II

$$SE_{D_e} = \frac{0.60 \times \sqrt{(1-0.78)}}{\sqrt{20}} = 0.058$$

$$SE_{D_c} = \frac{0.75 \times \sqrt{(1-0.78)}}{\sqrt{21}} = 0.077$$

$$SE_{D_d} = \sqrt{0.058^2 + 0.077^2}$$

$$= 0.10$$

$$t = \frac{0.95 - 0.52}{0.10} = 4.30$$

Using this method both these tests show significant increases on a one tailed t-test ($p<0.0005$ for Group Embedded Figures Test and $p<0.0005$ for Science Reasoning Task II).

DISCUSSION.

It was possible that the written item called 'Embedded Figures' gave practice at the 'Embedded Figures Test', the measure used to test for Field-independence. Although a different activity was used in the later studies the experimenter felt justified in its use: any materials designed to train a particular skill must have some relation between the training and the test given to evaluate their effectiveness. It is argued that the method of presentation of all the computer materials and three of the four written materials was sufficiently different from the test items to train for the skill but not give test practice. The 'Embedded figures' task was only one of eight tasks, and was given for only half an hour in a total training time of seven hours spread over the twelve week training period. The task used similar figures to the PRACTICE items of the Group Embedded Figures Test; these are not the same as the test itself. This hardly constituted long term training and is unlikely to seriously invalidate the study. It is therefore suggested this training showed that it is possible to train a cognitive style, i.e., Field-independence, (a measure generally accepted as desirable and often thought to be a stable personality trait and unmodifiable). As a consequence the training also helped pupils disembed variables from a problem and rearrange them to solve that problem. It also demonstrated that cognitive development was shown in an area not closely related to the training, i.e., Formal operations, as a result of Field-independence training. In no way could the training materials have been said to train for the test items on Science Reasoning Task II which is an accepted measure of estimating Formal operations. The results suggested that one of the difficulties pupils had in developing or demonstrating Formal operational thought was the inability to disembed the variables from other contextual information. This was one of the problems of the late deployers of Formal operations identified by Stone & Day (1980). The pupils needed to 'see' the variables for themselves. It is therefore concluded that the training enabled some of Stone & Day's 'late deployers' to isolate variables for themselves and they were then able to demonstrate Formal operations spontaneously. The conclusion is that training materials had increased the cognitive restructuring aspect of Field-independence and that this had enabled pupils to perform at a higher level on Science Reasoning Task II, an indirect measure of Formal Operations.

Chapter 5: 2nd Feasibility study.

Although the last study gave significant increases in Field-independence and Formal Operations it needed to be repeated;

1) to confirm the results of the first study with more subjects,
2) with an additional member of staff apart from the experimenter to use the materials;

Satterly (1979) suggests that development of a cognitive style such as Field-independence does not necessarily overlap with development of general intelligence. If this is the case then development of Field-independence in children can be overlooked by teachers if they are only using tests of general ability as a measure of cognitive development. In addition to the giving of tests for Field-independence and Formal Operations this study included tests for general ability to test a third hypothesis, i.e.;

3) whether the increases in Field-independence and Formal Operations were due to rises in general intelligence rather than increases in Field-independence or Formal Operations.

If Satterly's hypothesis is correct successful training in Field-independence should not have produced any significant increase in general ability. General ability was tested using Cognitive Abilities Tasks, (Thorndike & Hagan, 1973) which included tests of verbal, quantitative and non verbal ability.

SAMPLE

From an intake of 220 first year pupils in a rural comprehensive school a group of slow learners, identified by Primary school Richmond Test results, (Hieronymus, Lindquist & France, 1975), were removed from the sampling frame. The remaining 204 were divided into eight approximately equal mixed ability groups. The experimenter had no control over this process but there was no identifiable bias in placing pupils in groups.

The groups were then randomly assigned to members of staff. Three groups took part in the trial, two experimental groups and one control each taken by different staff one of whom was the experimenter. The three groups taking part in the trial were tested for;

1) Field-independence using the Group Embedded Figures Test (Oltman, Raskin, & Witkin, 1971).
2) Formal Operations using Science Reasoning Task II (NFER, 1979).
3) General ability using the Cognitive Abilities Tasks (Thorndike & Hagen, 1973).

The group's scores were then analysed using the Kolgromov-Smirnov test for the significance of the difference of distribution between the two experimental groups and the control group. Any differences in the experimental groups and the control group were NOT significant at $p<0.1$ (see appendix 2 for calculations). A summary of the findings are in table 5-1.

TABLE 5-1: KOLGROMOV-SMIRNOV TESTS FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN EXPERIMENTAL AND CONTROL GROUPS ON THE GROUP EMBEDDED FIGURES TEST, SCIENCE REASONING TASK II AND COGNITIVE ABILITIES TASKS.

Tests	expt.gp1		expt.gp2	
	D	χ^2	D	χ^2
GEFT	0.25	2.243	0.13	0.606
SRTII	0.05	0.090	0.13	0.606
CAT (verbal)	0.17	1.037	0.15	0.088
CAT (quantitative)	0.24	2.066	0.24	2.066
CAT (non verbal)	0.12	0.517	0.12	0.517
CAT (mean)	0.06	0.129	0.13	0.606

D=difference between accumulated proportions between experimental and control groups and is the figure used to test for significance in appendix 6.
NOT significant at $p<0.1$
expt. gp.1 & expt. gp.2 N=17; control group N=19.

The two experimental groups were given a combination of science teaching and training materials as described in the last chapter and appendix 3. The only difference was that another set of fifteen word searches were compiled to account for the different subject matter covered during this study and the 'continuo' game was introduced (see appendix 3). Appendix 3 gives detailed descriptions and the rationale of all the materials used in all the studies. The null hypotheses tested in this study were:

1) that after training there would be no significant difference in the mean scores between the Field-independence level of the experimental groups and the control group;
2) should the experimental groups be significantly more Field-independent this would not be associated with an increase in Formal Operational level;
3) other staff using the materials would not be able to increase the levels of Field-independence or Formal Operations;
4) any increases in Field-independence would be associated with an increase in cognitive ability;
5) any increase in Formal Operations would be associated with an increase in cognitive ability.

RESULTS

TABLE 5-2: MEANS AND STANDARD DEVIATIONS FOR PRE- AND POST-TEST SCORES ON GROUP EMBEDDED FIGURES TEST, SCIENCE REASONING TASK II AND THE COGNITIVE ABILITIES TASKS.

Group	N	Pre-test $\bar{X}$	Pre-test σ	Post-test $\bar{X}$	Post-test σ	Difference pre-post test $\bar{X}_2-\bar{X}_1$	Difference pre-post test σ
Group Embedded Figures Test							
Expt. gp 1	17	4.53	3.36	9.71	3.70	5.18	2.48
Expt. gp 2	17	5.65	4.60	11.23	3.63	5.59	2.50
Control	19	6.11	3.30	7.95	4.08	1.84	2.75
Science Reasoning Task II							
Expt. gp 1	17	2.67	1.00	3.46	1.01	0.82	0.95
Expt. gp 2	17	2.83	0.63	3.59	0.62	0.76	0.75
Control	19	2.68	0.67	2.90	0.57	0.21	0.79
Cognitive Abilities Tasks (mean)							
Expt. gp 1	17	110.41	12.84	115.17	14.80	4.76	5.82
Expt. gp 2	17	110.24	10.95	112.88	10.55	2.65	6.14
Control	19	107.68	10.35	111.11	12.12	3.42	5.47

TABLE 5-3: t-TESTS, EFFECT SIZES AND PERCENTILES BETWEEN EXPT. GPS. OVER CONTROL GROUPS ON THE DIFFERENCES BETWEEN THE DIFFERENCES BETWEEN PRE- AND POST-TEST SCORES ON GROUP EMBEDDED FIGURES TEST SCIENCE REASONING TASK II AND COGNITIVE ABILITIES TASKS MEAN.

	Experimental group 1			Experimental group 2		
	t-test	effect size	%tl	t-test	effect size	%tl
GEFT	8.73	0.92	0.82	9.76	0.95	0.95
SRTII	4.36	0.74	0.87	4.43	0.89	0.89
CAT(avg)	2.45 a	0.24	0.59	-1.37 b	<0	

Experimental groups 1 & 2 N=17, control group N=19.
a=significant $p<0.025$, b=non significant, all other results significant at $p<0.0005$.
Full results detailing the individual Cognitive Abilities Tasks scores appear in appendix 2.

One tailed t-tests were calculated using test reliabilities of 0.82 for Group Embedded Figures Test, 0.78 for Science Reasoning Task II and 0.93 for the mean of the Cognitive Abilities Tasks. The results of t-tests between unmatched experimental groups and control group for the difference of the differences between pre- and post-test scores showed significant increases in Field-independence and Formal Operations in experimental group subjects over control group subjects at $p<0.0005$. This was verified using MacNemar's calculation with test reliabilities as above (see chapter 4 for discussion and appendix 2 for calculations). The results were confirmed using effect sizes as detailed in chapter 3 and presented, as suggested by Rosenthal (1978) and Smith & Glass (1981, 1977), in diagrams 5-1 to 5-4 showing that in the case of Group Embedded Figures Test 82% of experimental group 1 and 76% of experimental group 2 were scoring higher than the mean of the control group pupils. In the case of Science Reasoning Task II 77% of experimental group 1 and 79% of experimental group 2 were performing higher than the mean of the control group pupils. The percentiles were derived from the table reproduced in appendix 7. The results for the Cognitive Abilities Tasks were not so clear, one experimental group giving significant increases $p<0.025$ the other no significant difference. When the results of the two groups were merged there was no significant increase.

FIGURE 5-1: SHADED AREA SHOWS 82% OF EXPERIMENTAL GROUP 1 ARE BETTER THAN THE MEAN OF THE CONTROL GROUP PUPILS ON THE GROUP EMBEDDED FIGURES TEST

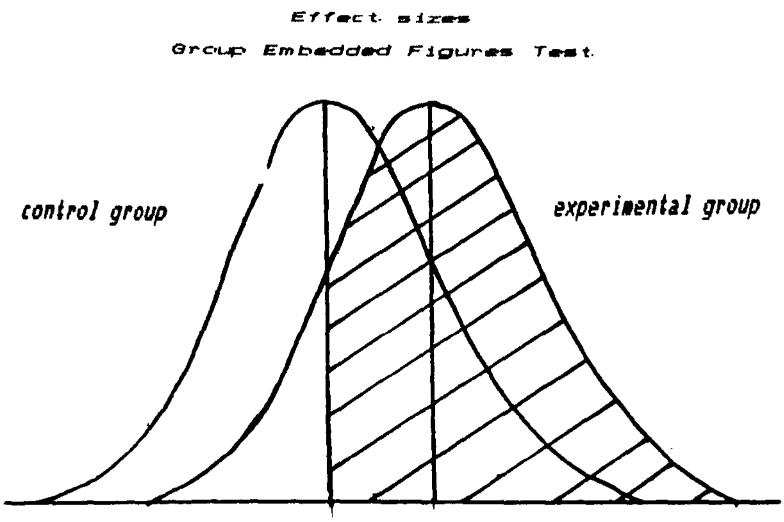


FIGURE 5-2: SHADED AREA SHOWS 76% OF EXPERIMENTAL GROUP 2 ARE BETTER THAN THE MEAN OF THE CONTROL GROUP PUPILS ON THE GROUP EMBEDDED FIGURES TEST.

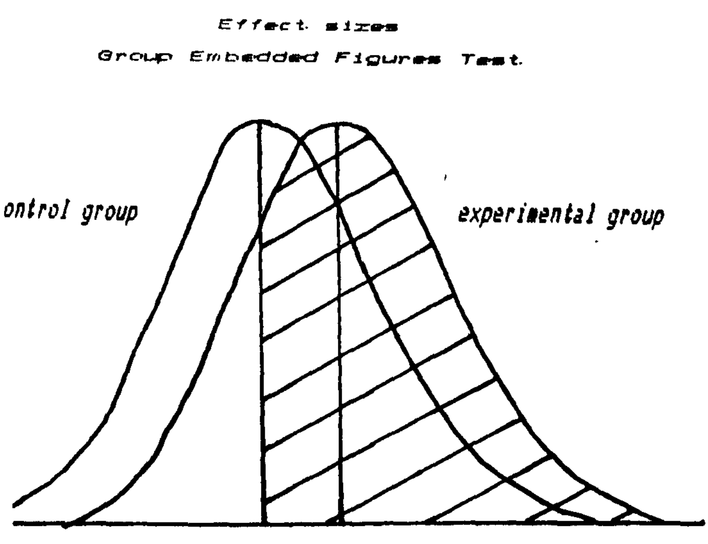


FIGURE 5-3: SHADED AREA SHOWS 77% OF EXPERIMENTAL GROUP 1 ARE BETTER THAN THE MEAN OF THE CONTROL GROUP PUPILS ON SCIENCE REASONING TASK II.

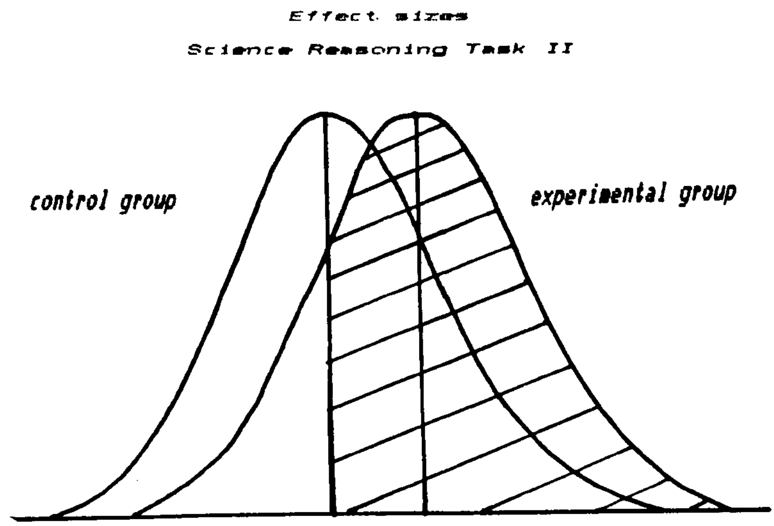
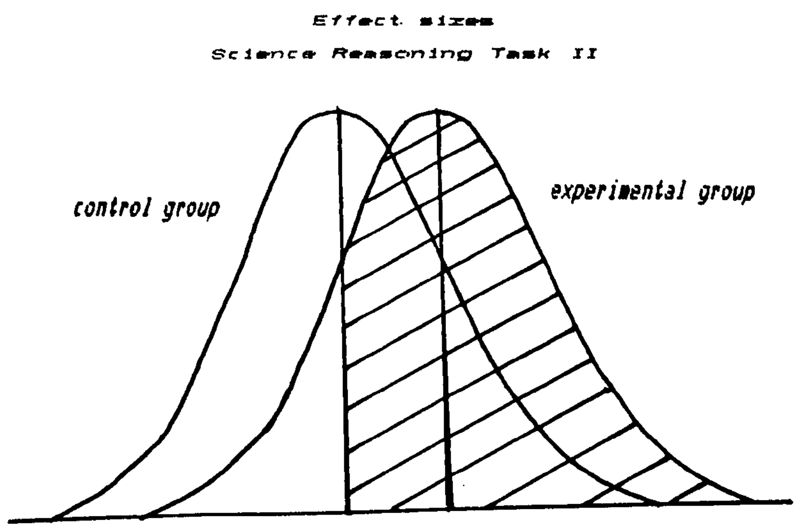


FIGURE 5-4: SHADED AREA SHOWS 79% OF EXPERIMENTAL GROUP 2 ARE BETTER THAN THE MEAN OF THE CONTROL GROUP PUPILS ON SCIENCE REASONING TASK II.



DISCUSSION.

These results therefore rejected the null hypotheses 1-4 tested in this study which were:

1) *that after training there would be no significant difference in the mean scores between the Field-independence level of the experimental groups and the control group;*
2) *should the experimental groups be significantly more Field-independent this would not be associated with an increase in Formal Operational level;*
3) *other staff using the materials would not be able to increase the levels of Field-independence or Formal Operations;*
4) *any increases in Field-independence would be associated with an increase in cognitive ability;*

The experiment is interpreted as follows:

1) *confirming the results of the 1st feasibility study, i.e., that a training in Field-independence will not only produce increases in Field-independence but will also produce parallel increases in Formal Operations;*
2) *staff other than the experimenter could produce similar results;*
3) *that it was possible to train for Field-independence by giving practise and training in careful observation, isolation of the particular from the general and restructuring of information;*
4) *training in Field-independence produced parallel increases in Formal Operations although no structured training of Formal Operations was given;*

There were contradictory results with the Cognitive Abilities Tasks. If the individual task scores are considered (appendix 2) then some show *significant increases, some significant decreases and others no significant differences over controls. These are sometimes confounded within the experimental groups, i.e., one group showing a significant increase the other a significant decrease. This means that null hypothesis 5 can be accepted or rejected depending on which experimental group is used for the comparison. The results are therefore inconclusive. In an attempt to clarify the results and to get some indication of direction of the trend the two experimental groups were merged and treated as one experimental group of 34. This showed that there was no significant increase over the training period in the pupils' cognitive ability mean score. There was therefore some indication that the Cognitive Abilities Tasks do not measure Field-independence or Formal Operations giving support to Satterly's view that general ability and cognitive style do not overlap. The results also suggest that children may perform in a scientific way as assessed by the Group Embedded Figures Test and Science Reasoning Task II but this may not be obvious if only tests of general ability are used as measures. It was argued in Chapter 2 that Piagetian levels of development are important in scientific thought. The Cognitive Abilities Tasks appear not to measure scientific ability. It is therefore important that teachers take this into account when assessing a pupil's scientific ability or potential.*

Chapter 6: Materials development for Final study.

As both the feasibility studies had shown significant increases in Field-independence and consequently Formal Operations, a more comprehensive study was planned. It was envisaged that the training would take a whole academic year, more groups would be trained and that the materials should be integrated as much as possible into the work the children did, rather than taking specific time out of lessons for training. Some time was taken for training in the development of a meta-cognitive language with two of the experimental groups but this is a separate issue discussed in the next chapter. If the training was going to be integrated and serve more groups a reappraisal of the training materials was necessary.

The children worked from work cards that the school had produced in conjunction with cards produced from the ILEA scheme Insight to Science (1979). This meant rewriting some of the twelve topics completely and extending others, some 56 cards; integrating the ideas developed so far, and finding many new activities that emphasised the skills being developed. An example of one complete topic appears in appendix 3. Appendix 3 gives detailed descriptions, with rationale, of all the materials used in all the studies but a brief description of the extra ones developed for this study follows.

In an attempt to integrate the activities as much as possible into the pupils normal work, a major source of stimulus for the materials were the key words, sentences and paragraphs within each of the twelve topics. This not only developed Field-independent skills but also rehearsed the content of the work cards. A description of the new materials developed for this study follows.

Reorganising sentences.

The words of key sentences that appeared on the card were randomly shuffled using a computer program written by the experimenter. The task for the pupil was to rearrange these to reproduce the original sentence, e.g.;

liquid and a is solid ink out of found a have that mixture you a.

You have found out that ink is a mixture of a solid and a liquid.

On average about ten of these were produced for each topic making about 120 in all.

Anagrams

These were shuffled letters (using a computer program written by the experimenter) from key words in the topic being studied. There were usually about 20 to 30 words in each topic that could be used, about 300 in all. These were grouped into tens or twelves and used as the basis of the topic's word searches. If the children solved the anagrams they had the words in the related wordsearch or if they solved the wordsearch they had the words to match with the anagrams.

TABLE 6-1: 'ANAGRAMS AND SOLUTIONS'.

Anagram	Solution	Anagram	Solution
riiuefepd	purified	idrutb	turbid
ilesetr	sterile	lislg	gills
eciadnbut	incubated	dlkeli	killed
srloa	solar	mlua	alum
atwre	water	ylupsp	supply
oclos	cools	peip	pipe
tdcseaoris	desiccator		

Wordsearches

DIAGRAM 6-1: EXAMPLE OF 'WORDSEARCH'.

Wordsearch created from the words above.

N	I	M	E	L	I	R	E	T	S
I	N	C	U	B	A	T	E	D	T
B	U	V	S	H	I	N	Y	M	I
A	V	G	W	D	W	W	Z	Y	L
C	H	E	M	I	C	A	L	S	L
T	J	E	L	S	E	T	Y	O	K
E	Y	T	O	E	O	E	B	L	P
R	T	L	O	H	O	R	W	A	W
I	B	A	C	S	R	X	Y	R	X
A	F	S	Z	E	Y	C	E	S	P

Two or three, sometimes four of these were compiled per topic making about 40 in all.

Sentences with gaps

This entailed putting the gaps between the words in the right places. Initially this was done with a computer program written by the experimenter to randomize the position of the gaps but it was too easy. Later, as in the example below (which is part of a longer version), some attempt was made to make new words from the beginnings and endings of other words thus producing a distracting field.

TABLE 6-2: EXAMPLE OF 'SENTENCE GAPS'.

W he nsa ltisp lace din wa terand stir redit disap pear sthes a lt d iss ol vesint hew ater itisstill thereeven th ou gh it can notbes eenwa terwhi chhas ltdis solve dinit isc all edaso lutio nth eli quid par tofas olut ion iscall e dth esol utesom emat er ialsdo n otdis solve.

When salt is placed in water and stirred it disappears. The salt dissolves in the water. It is still there even though it cannot be seen. Water which has salt dissolved in it is called a solution the liquid part of a solution is called the solute. Some materials do not dissolve.

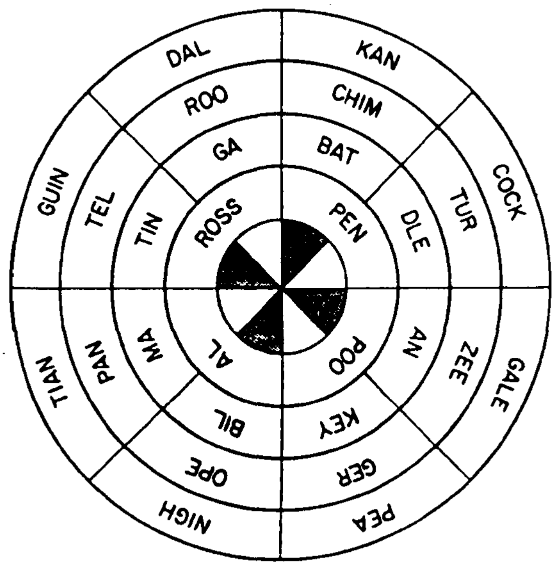
Word puzzles

They were taken from a book of 'Word Teasers' by Veronica Millington (1985). They were used for the most able as they emphasised problems similar to those used here but were more difficult. An example follows.

DIAGRAM 6-2: EXAMPLE OF A 'WORDPUZZLE'.

Mixed-up Animals

Combine the syllables in the circle to make the names of five birds and six mammals. Each syllable may be used once only. You may need more than two syllables to complete a name.



Random experiments

This activity gave pupils the method to carry out an experiment but the order was shuffled. Sometimes this was an experiment they had carried out. Sometimes a novel situation was used but calling on experience they had gained from lessons. About fifteen of these were created.

Clueless crosswords

DIAGRAM 6-3: EXAMPLE OF CLUELESS CROSSWORD.

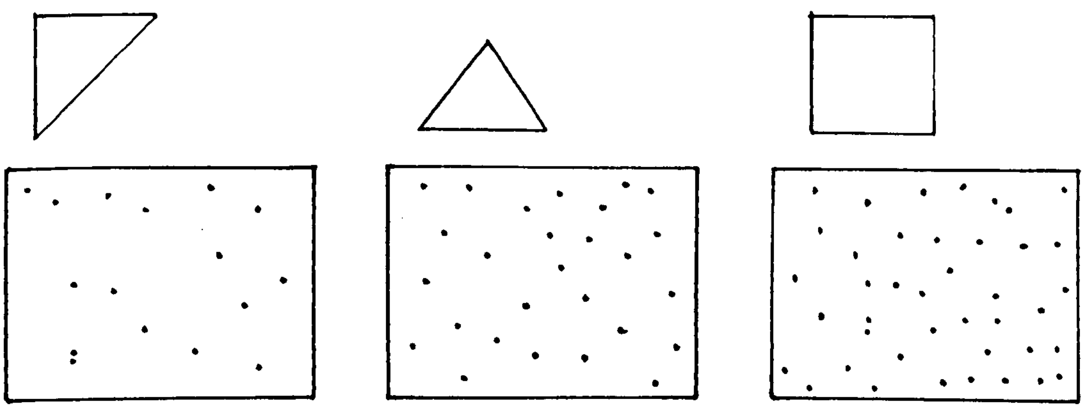
17	13	2	2	1	24	24	XX	7	14	15	24	1	19	1	2
							XX								
6	XX	XX	14	XX	1	XX	XX	25	XX	6	XX	XX	25	3 K	4
	XX	XX		XX		XX	XX		XX		XX	XX			
26	XX	XX	9	12	6	10	16	24	1	17	XX	XX	21	5	6
	XX	XX									XX	XX			
15	14	10	3	XX	7	XX	XX	16	XX	2	6	6	17	7	8
				XX		XX	XX		XX						
25	XX	XX	24	25	13	5	6	14	10	XX	15	XX	13	9	10 N
	XX	XX								XX		XX			
10	6	5	1	XX	1	XX	XX	10	XX	XX	25	6	3	11	12
				XX		XX	XX		XX	XX					
16	XX	14	XX	XX	XX	XX	6	7	6	19	1	XX	XX	13	14
	XX		XX	XX	XX	XX						XX	XX		
XX	XX	17	25	13	2	1	XX	XX	XX	XX	21	XX	26	15	16
XX	XX						XX	XX	XX	XX		XX			
9	25	7	XX	XX	4	XX	XX	9	XX	16	6	24	14	17	18
			XX	XX		XX	XX		XX						
14	XX	14	XX	17	25	2	2	14	10	14	XX	XX	24	19	20
			XX	R	O	S	S	I	N	I	XX	XX			
5	6	24	1	XX	17	XX	XX	9	XX	8	8	14	24	21	22
				XX		XX	XX		XX						
14	XX	XX	21	1	17	19	17	6	10	16	XX	XX	14	23	24
	XX	XX									XX	XX			
9	XX	XX	21	XX	6	XX	XX	16	XX	1	XX	XX	6	25	26
	XX	XX		XX		XX	XX		XX		XX	XX			
2	1	24	26	20	10	XX	9	6	16	15	14	13	15		
						XX									

Here numbers were substituted for letters. The pupils were given two letters and their representative numbers and also one word in the crossword. The task was to match the letters to the numbers by ubstitution to solve the whole crossword. The experimenter produced fifteen of these similar to the example above.

Figures in a dot maze

This was a direct adaptation of work on Instrumental Enrichment by Feuerstein et al. (1980). Feuerstein's work is discussed in more detail in the next chapter. The task required pupils to find the geometric shape given, e.g., triangle or square in a maze of dots. This was complex to produce. The experimenter wrote a computer program which accepted the coordinates for the solution then produced either twelve, twenty four or thirty six distracting dots randomly. This was printed and photo reduced to produce a book of one hundred and eight problems. Below is an example of a right-angled triangle in twelve distracting dots, an equilateral triangle in 24 distracting dots and a square in 36 distracting dots.

DIAGRAM 6-4: EXAMPLE OF 'FIGURES IN A DOT MAZE'.



Spot the difference

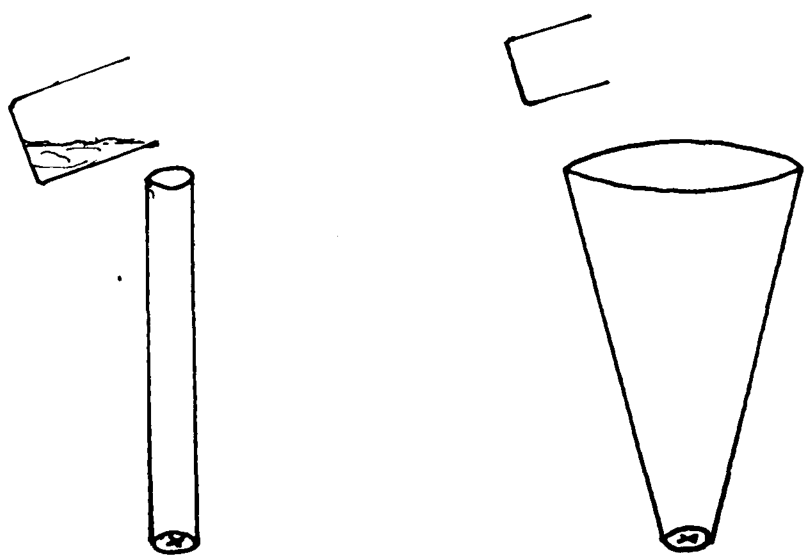
These were pairs of seemingly identical pictures or cartoons in which one of the pair showed some subtle differences. The task was to identify the differences. Five of these were produced.

A similar activity to the above was used with diagrams of scientific apparatus.

Comparison of diagrams and the significance of differences

Pupils were given a correct example of a diagram of the apparatus they had been using in an experiment. They were then given five other versions that had some differences in them. The pupils' task was first to identify the differences and then to state how significant these differences were, i.e., would they stop the experiment working as required? An example of a correct diagram with one variation rather than the usual five is shown below. One of these was usually produced per topic sometimes two, making fourteen in all.

DIAGRAM 6-5: EXAMPLE OF 'DIAGRAM COMPARISON'.



Extracting items of narrow criteria from a table of complex information.

This was a complex task and is best described with an example.

Example from topic 11 of extraction of information from a table.

Look carefully at the following table and then answer the questions below

Name of flower	No. of sepals	No. of petals	No. of stigma	No. of stamens	Col. of petals	Pollen present	Smell
Polygonum	yes	6	3	9	red	yes	yes
Rhododendron	5	5	5	5	pink	no	yes
Orchid	yes	6	3	1	yellow brown	no	yes
Buttercup	3	10	11	25	yellow	no	no
Lily	5	5	4	5	white	yes	yes

Which flower has;

1. 5 petals, 5 sepals has pollen and smells____________________

2. more than 8 stigma, 10 stamens, no pollen, doesn't smell and has petals that <u>are not</u> green or red.

____

3. petals that are red or yellow, has less than 10 stigma, less than 10 stamens and has pollen present

____

4. the same number of petals, sepals, stigma and stamens.____________________

Below is a list of all the materials used and the numbers produced for the final study.

Random pictures	as before	Matching rows	as before
Shape in shape	as before	Pattern	as before
Continuo	as before	Reorganising sentences	120
Anagrams	300	New wordsearches	40
Sentences with gaps	15	Word puzzles	10
Random experiments	15	Clueless crosswords	15
Figures in a dot maze	108	Spot the difference	5
Comparison of diagrams	14	Criteria from tables	5
Rewritten topic cards	56		

These new materials were trialed in the spring and summer terms of 1985 in preparation for the new academic year 1985/6. There were no major changes but it did enable removal of errors and better means of production and presentation.

It was proposed to train three groups using these materials. Two of the groups were also to have training in developing a meta-cognitive language to express the skills learnt in the training. This aspect is discussed in the next chapter.

Chapter 7: The influence of Feuerstein on the interpretation of the thesis.

Introduction.

Feuerstein, and his theory of Mediated Learning Experience, meta-cognitive language and bridging, profoundly influenced the way in which the rest of this thesis was interpreted by the experimenter. There were strong parallels between;

1) Field-independence and aspects Feuerstein's Mediated Learning Experience,

2) the training materials in this thesis and those of Feuerstein.

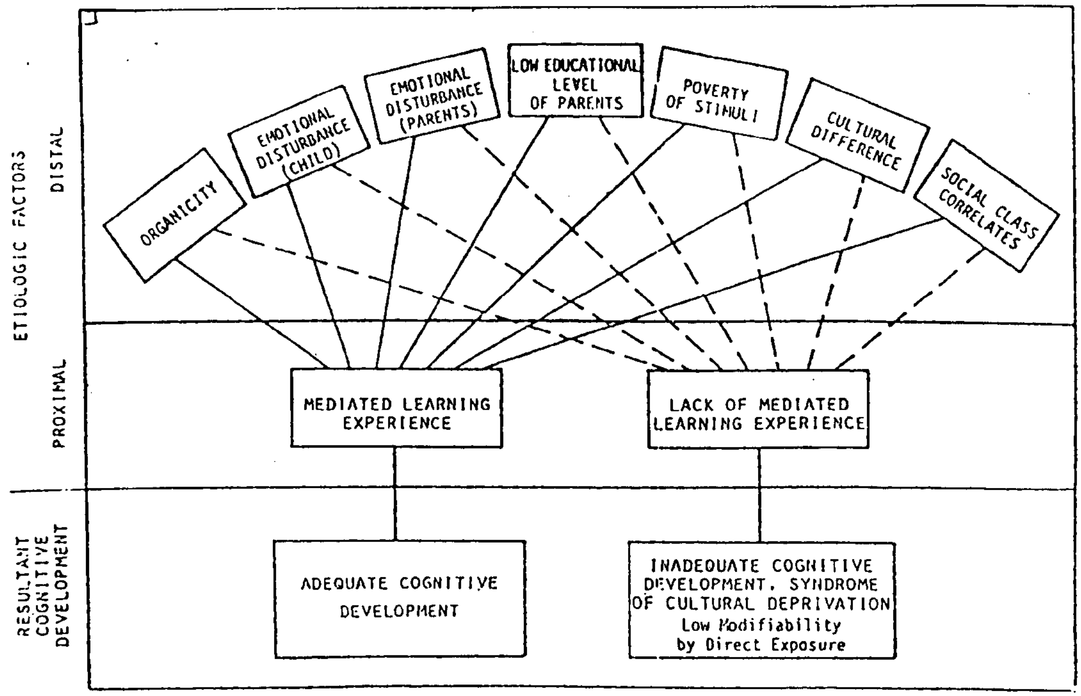
The process of developing a meta-cognitive language about the childrens' thinking and 'bridging' this to new familiar situations used by Feuerstein was seen as a possible way of enhancing this investigation. Before discussing these points there follows a summary of the relevant parts of Feuerstein's work.

Feuerstein's work and Mediated Learning Experience.

Feuerstein's work was with culturally deprived subjects. His aim was not to teach individuals any new content but to change their basic cognitive structure. The corner stone of his idea was that people who are culturally deprived are deprived of Mediated Learning Experience. Feuerstein et al. (1980) p. 15,16, described Mediated Learning Experience, as '... the way in which stimuli emitted by the environment are transformed by a 'mediating' agent, usually a parent, sibling or other caregiver. This mediating agent, guided by his intention, culture and emotional investment, selects and organizes the world of stimuli for the child. The mediator selects stimuli that are most appropriate and frames, filters, and schedules them; he determines the appearance and disappearance of certain stimuli and ignores others'. It is contended that these are the skills developed by Field-independent subjects and it *is therefore likely that Mediated Learning Experience could assist the acquisition of Field-independent skills.*

Feuerstein saw two determinants of differential cognitive development; the distal and the proximal. Distal factors included, genetic, environmental stimulation, parents and socio-economic status. These could lead to inadequate cognitive performance, i.e., they did not directly or inevitably cause retardation. The proximal factor was lack of Mediated Learning Experience which did cause retardation. Feuerstein et al. suggested that the cause of retardation was not the distal factor so often blamed for retardation but the proximal factor, i.e., lack of Mediated Learning Experience. Any one or combination of the distal factors may have been responsible for lack of the proximal factor see diagram 7-1. Feuerstein et al. suggested that if focus is put on supplementing inadequate Mediated Learning Experience rather than on distal factors that cannot be changed it is possible to enhance cognitive development. Feuerstein et al. saw Mediated Learning Experience as 'a group supported activity which is generated by a primary need of human societies to preserve their cultural continuity' (1980, p. 20). Any interaction that provided Mediated Learning Experience must include intention and transcend the immediate need. Instruction with explanations would be a Mediated Learning Experience as they form orientation to allow a child to form constructs to put the immediate into mental schemes of their own, thus developing cognitive efficiency. 'Put that knife down you may cut yourself' would be a Mediated Learning Experience whereas 'put that down' would not. The content is not seen as very important. It is only a vehicle for developing an understanding of processes. Many types of content can develop the same process. For example it does not matter whether a *child organizes books by title or author; nuts and bolts into sizes; cutlery into knives, spoons, large forks and little forks; cuisenaire rods into colours or shapes, the basic cognitive process of organizing and reorganizing is still the same.*

DIAGRAM 7-1: DISTAL AND PROXIMAL ETIOLOGIES OF DIFFERENTIAL COGNITIVE DEVELOPMENT. (ADAPTED FROM FEUERSTEIN AND RAND (1974)).



Piaget was also aware of the importance of repetitive interaction with objects to form schemata, and social interaction is one of the four factors Piaget listed as necessary to develop cognition (Piaget, 1964). Mediated Learning Experience can be transmitted in many modalities, i.e., gesture, mimicry, general behaviour or observation. As neither specific content nor modality are crucial to the mediating process of Mediated Learning Experience, it is a universal phenomenon. Its efficiency can be effected by language and or content but not the process itself. 'Mediated Learning Experience produces in an organism a propensity to learn how to learn', Feuerstein et al. (1980, p. 25). Thus a child without Mediated

Learning Experience has to make the best use it can of meaning of the surroundings, usually unsuccessfully. Feuerstein suggests that another step is put into Piaget's Stimulus-Organism-Response system for building up schemata, i.e., H, Human mediator thus S-O-R becomes S-H-O-R.
Feuerstein also suggested that tests given to assess a child's ability only did so against a norm for subjects of that age. Cognitive or psychometric tests did not measure the capacity of the subject to improve. Feuerstein decided that it was the subject's inherent ability to improve that was important, not their absolute score on any given test. He conceived the Learning Potential Assessment Device, to assess not the subjects' score on any absolute scale but rather their potentiality for improvement (a more detailed description of the Learning Potential Assessment Device appears in appendix 8). Broadly this was determined by taking detailed notes whilst administering tests and recording how much prompting of the meta-strategies was necessary to enable the subject to succeed, and how much the subject improved consequently without such prompting. Subjects were not allowed to fail only insomuch as to determine the point of failure and the degree of help needed to succeed.

Feuerstein's intervention to overcome lack of Mediated Learning Experience was a series of pencil and paper exercises aimed at developing various cognitive functions. These were given two or three times a week for TWO YEARS. The aim of Feuerstein's material was to produce substitute Mediated Learning Experiences to increase cognitive function, and so to increase performance. Feuerstein's intervention produced significant improvements. Shayer and Beasley (1987) in ideal conditions have shown increase of 1-1.25 of a standard deviation on the Learning Potential

Assessment Device, Ravens Advanced Matricies and Piagetian Operations with subjects considered to be well below average on standard tests.

Once the subjects' learning potential had been established they were given material suitable to develop the cognitive function or functions in which they were deficient. The materials given were designed to substitute for lack of Mediated Learning Experience. Feuerstein asserts that no individual acts or learns in isolation. A child's surroundings are interpreted and mediated for the child either by the parents, other adults or older children. Even older children moderate or alter their language when talking to younger children or babies. As adults we also like mediation when dealing with new or complex ideas. Feuerstein contended that any children denied this intercession between them and the world are culturally deprived. Children do not develop many of the cognitive functions, listed in appendix 8, which allow them to make efficient use of their brains, nor do they make use of many of the available opportunities for learning. Children are then incapable of using the capacity of their brains because they do not have the cognitive functions to use that facility. If this is the case then Feuerstein claims that children can be given experiences that develop these cognitive functions and so enable them to use more of their mental potential.

Similarities Between Field-independence & Feuerstein's work.

There are important similarities between the approach of this study and Feuerstein's work. This intervention in no way matched Feuerstein's formidable study but this study could be interpreted within his view of cognitive functioning. An aspect of Formal Operations is the necessity to isolate and manipulate variables. If the variables cannot be identified because of lack of the cognitive function Field-independence, then it is unlikely that a child will display Formal Operational thought. If Field-independence can be increased by training or Mediated Learning Experience then any child not being able to carry out Formal Operations because of lack of Field-independence would be able to do so.

In discussing mediated learning Feuerstein et al. (1980, page 27) describe a close description of the cognitive restructuring aspect of Field-independence, '... a care-giver gives saliency to particular stimuli and gives example to being selective in perception and ignoring irrelevance .... Children not having had Mediated Learning Experience tend to be hyperprosexic, children scan their perceptual environment without attending differentially to the more relevant elements and therefore do not persist in developing the means for attending specific goals'. Feuerstein et al. (1980, page 34) also identifies comparative behaviour as being of great importance. '... the precursors of comparative behaviour involve the orientation of the organism towards increasingly precise procedures of perception, exploration and attention'.

Field-independence could be viewed as using some of the modalities of the Learning Potential Assessment Device, see appendix 8, i.e., spatial, pictorial, figural etc. within the operation of disembedding the simple from the complex. It also contained the skills that are used in Mediated Learning Experience, i.e., 'framing, selecting and scheduling information'. These are just different words for the processes the experimenter was trying to develop in Field-independence.

This study is concentrating on processes such as;

1) disembedding the simple from the complex,
2) reorganising information to produce new patterns so breaking up a visual field and recreating it,
3) looking for hidden information systematically,
4) comparison, noting differences and similarities,
5) ignoring irrelevant and confusing material,
6) ignoring basic Gestalt theory of organising visual field into a coherent whole rather than its constituent parts.

There are similarities in Feuerstein's Instrumental Enrichment cognitive functions phase parameter listed in appendix 8, and those identified in this study listed above see table 7-1.

TABLE 7-1: SIMILARITIES BETWEEN FEUERSTEIN'S PHASE PARAMETER AND PROCESSES REQUIRED FOR THE RESTRUCTURING ASPECT OF FIELD-INDEPENDENCE.

Feuerstein's parameter phase. (Numbers relate to those in appendix 8)	This study's processes (Numbers relate to those) above).
II1 analysing disequilibrium	1 & 3 & 6
II2 relevance	1 & 5
II3 comparative behaviour	4
II5 summative behaviour	2 & 3
II6 projecting relationships	2

In addition Feuerstein et al. (1980, chapter 4) describe how deficient cognitive functions were identified. Three phases to any mental act were described; input, elaboration and output, elaboration being the most important. Many of the deficiencies he identified within the input and elaborative phase, detailed in appendix 8, show strong links with Field-independence these are listed below.

Input

1) *Blurred and sweeping perception.*
2) *Impulsivity and unplanned behaviour.*
3) *Lack of verbal skills; (not directly relevant).*

4/5) *Lack of or impaired spatial and temporal orientation, e.g., not being able to organise a field by upper left & lower right.*

6) *Lack of or impaired conservation of consistencies.*
7) *Lack of or impaired need for precision and accuracy.*
8) *Lack of or impaired use of two sources of information used in such tests as Learning Potential Assessment Device (I) and Ravens Advanced Matricies.*

Elaboration

1) *Inadequacy in experiencing the existence of and subsequently defining a problem, (not directly relevant).*
2) *Inability to select relevant as opposed to irrelevant clues in defining a problem.*
3) *Lack of or impaired, spontaneous comparative behaviour.*
4) *Narrowness of the mental field, (not directly relevant).*
5) *Summative behaviour, (not directly relevant).*
6) *Virtual relationships, reorganising of information into a new situation.*
7) *Need for pursuing logical evidence, (not directly relevant).*

8) Interiorization, moving from the need to have concrete factor, cannot plan.

9) Planning setting goals not available in the here and now.

Diagram 7-3 shows which of the materials developed in this thesis trained for the cognitive deficiencies categorized by Feuerstein listed above and identified as associated with Field-independence by the experimenter. These include the materials used in the final study. A detailed explanation of all the materials appears in appendix 3.

DIAGRAM 7-3: RELATIONSHIP BETWEEN FEUERSTEIN'S COGNITIVE DEFICIENCIES WHICH INCLUDE FIELD-INDEPENDENT ASPECTS, AND TRAINING MATERIALS IN THIS STUDY.

		W	R	E	C	8	Rp	M	P	S	A	Cl	G	E	Dm	Sd	Cs	Re	Ss
Input	1	#	#	#	#	#	#	#	#	#	#		#	#	#	#	#	#	#
	2	#		#	#			#	#	#	#	#	#	#	#	#	#		#
	4/5	#	#	#	#		#	#	#	#		#			#	#	#		
	6		#	#			#	#	#	#					#	#	#		
	7	#		#	#		#	#	#	#	#	#	#	#	#	#	#	#	#
	8				#	#	#	#	#			#			#	#	#		
Elaboration	2	#		#	#	#		#	#	#	#	#	#	#	#	#	#		#
	3	#		#	#		#	#	#	#	#	#		#	#	#	#		
	6	#	#		#	#				#	#			#				#	#
	8	#		#	#	#		#	#	#	#	#	#		#	#	#	#	#
	9				#													#	

W=wordsearch, R=rearrange, E=embedded figs., C=continuo, 8=eightwords, Rp=random pictures, M=matching rows, P=pattern, S=shape in shape, A=anagrams, Cl=clueless crosswords, G=gaps in sentences, E=extracting info. from tables, Dm=dot maze, Sd=spot the difference, Sc=comparison & significance, Re=Random experiments, Ss=shuffled sentences.

Similarities between Feuerstein's training materials and those developed for this thesis.

There is not only similarity in the cognitive functions being developed by Feuerstein and the experimenter but there are also similarities in the materials themselves. It is not productive to describe all his training material here but merely to show that some similarity exits. Feuerstein et al. (1980) list 12 instruments; Organisation of dots, p.128, Orientation in space, p.144, Comparisons, p.163, Categorisation, p.175, Analytical perception, p.183, Family relations, p.193, Temporal relations, p.203 Numerical progressions, p.211, Instructions, p.200, Illustrations, p.230, Representational stencil design p.239 and Syllogisms, p.251.

The eighteen different materials developed or used by the experimenter were not used in all the studies but are included here for comparison. The experimenter's material can be grouped into three sections:

Comparison; *Random pictures, Matching rows, Pattern, Clueless crossword, Spot the difference, Comparison and significance,*

Rearranging; *Rearranging, Eight words, Anagrams, Extracting information, Random experiments, Shuffled sentences,*

Disembedding: *Word searches, Embedded figures, 'Continuo', Shape in shape, Gaps in sentences, Dot maze.*

TABLE 7-4: COMPARISON BETWEEN FEUERSTEIN'S MATERIALS AND THOSE DEVELOPED IN THIS THESIS.

Feuerstein's Materials	This study's materials																	
	Comparison						Rearranging						Disembedding					
	Rp	M	P	Cl	Sd	Cs	R	S	A	E	Re	Ss	W	E	C	S	G	D
Org. Dots																		#
Orr. in space			#			#					#							
Comparison	#	#	#	#	#	#												
Categorization								#	#									
Analytic perc.			#													#	#	
Family relat.																		
Temp. relations																		
Num. Progress.																		
Instructions												#						
Illustrations																		
Stencil design																	#	
Trans relat.																		

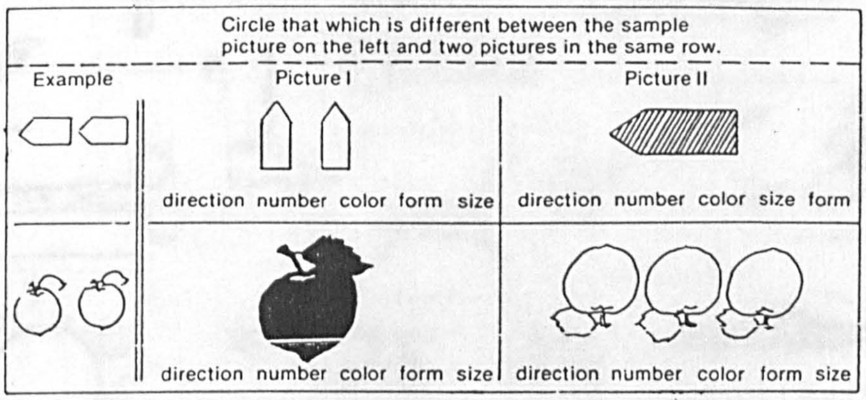
W=wordsearch, R=rearrange, E=embedded figs., C=continuo, 8=eightwords, Rp=random pictures, M=matching rows, P=pattern, S=shape in shape, A=anagrams, Cl=clueless crosswords, G=gaps in sentences, E=extracting info. from tables, Dm=dot maze, Sd=spot the difference, Sc=comparison & significance, Re=Random experiments, Ss=shuffled sentences.

It is obvious from diagram 7-4 that there are a wide range of cognitive functions that were being trained for in Feuerstein's work that were not applicable to these studies, however there were parallels in each of the three areas that had been identified as Field-independent skills. Listed below are brief descriptions of some of Feuerstein's training instruments which compare most closely with the training materials developed in this thesis.

Comparison/Comparisons

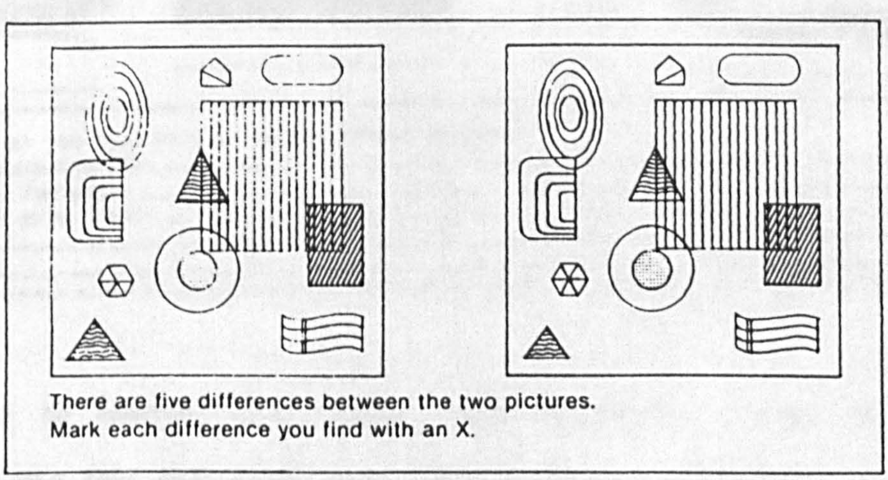
Ibid p.163, '...comparative behaviour is the most elementary building block of relational thinking and therefore a primary condition for any cognitive process that is to transcend mere recognition and *identification'. Ibid p.164, 'Comparative behaviour plays an important role in perception. To a large extent, it determines the nature of the perception, the acuity and sharpness of the perceived elements, and the precision with which various elements are registered'. The aims of this instrument were very similar to the aims of this study.*

Ibid page 165



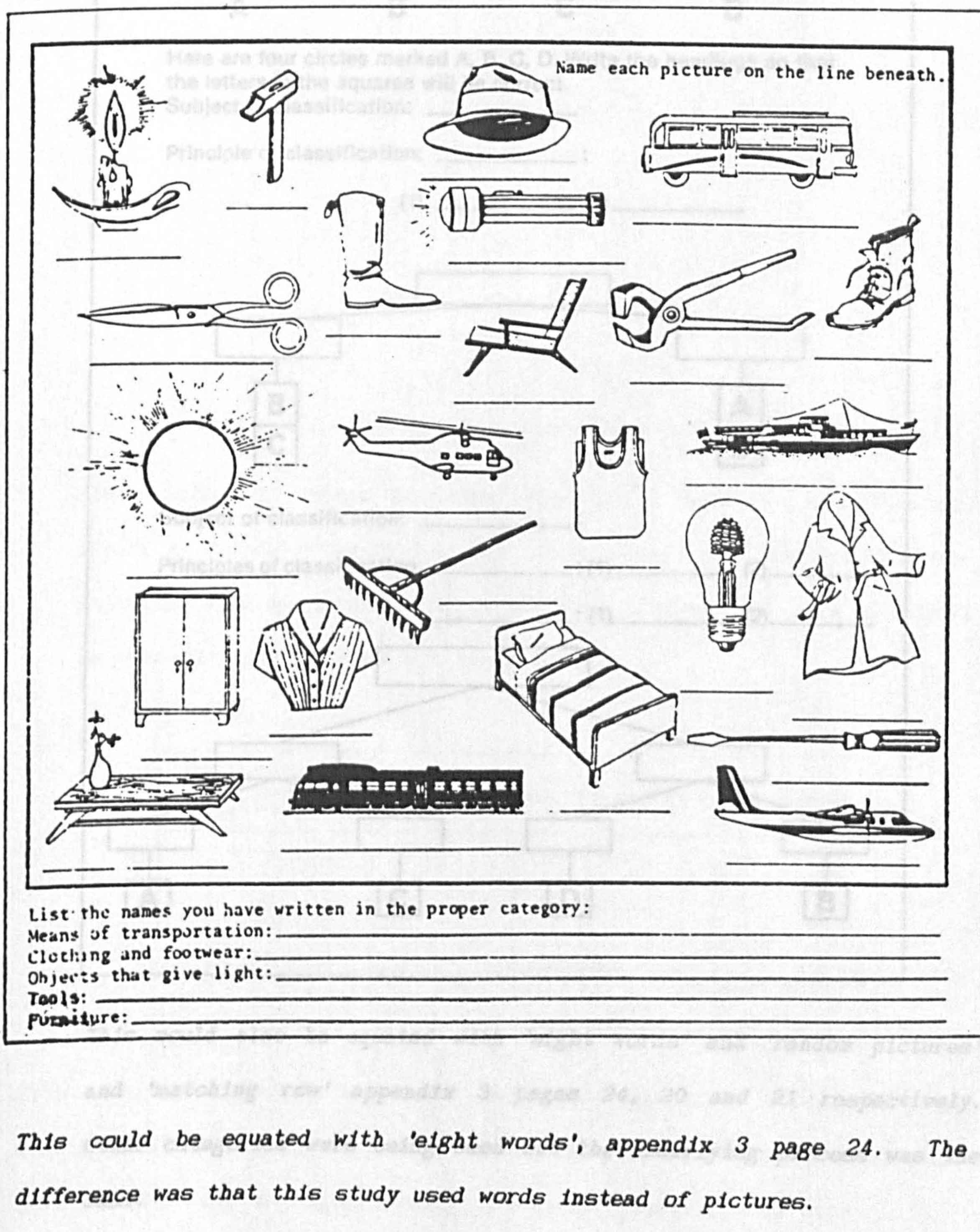
Although not exact there were similarities between the above and 'comparing and significance', appendix 3 page 40

Ibid page 166



There were obvious similarities between the above and 'matching rows' appendix 3 page 21, 'spot the difference' appendix 3 page 39 and 'pattern' appendix 3 page 27.Rearranging/Categorization.

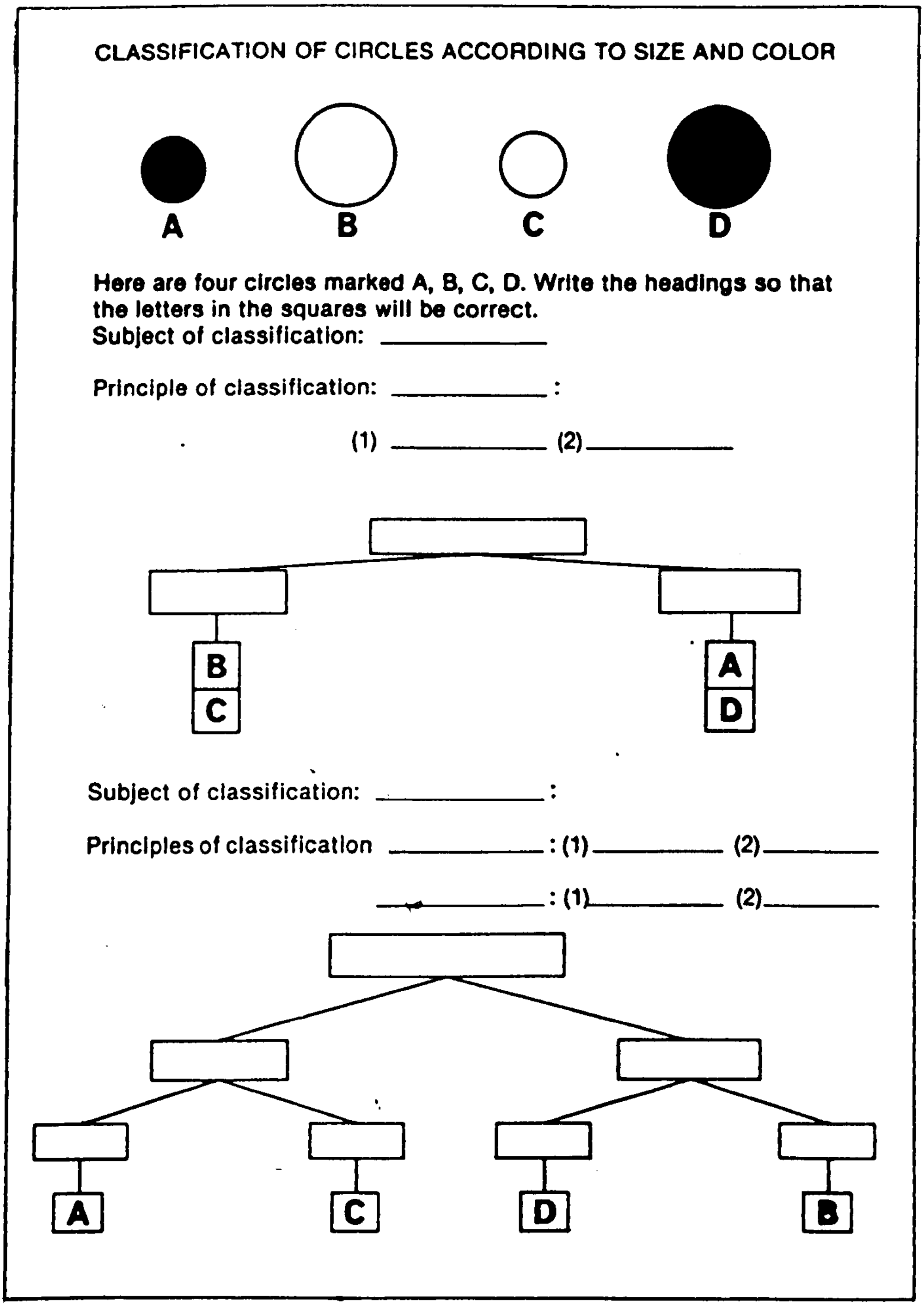
Ibid page 177.


Name each picture on the line beneath.

List the names you have written in the proper category:
Means of transportation: ____
Clothing and footwear: ____
Objects that give light: ____
Tools: ____
Furniture: ____

This could be equated with 'eight words', appendix 3 page 24. The difference was that this study used words instead of pictures.

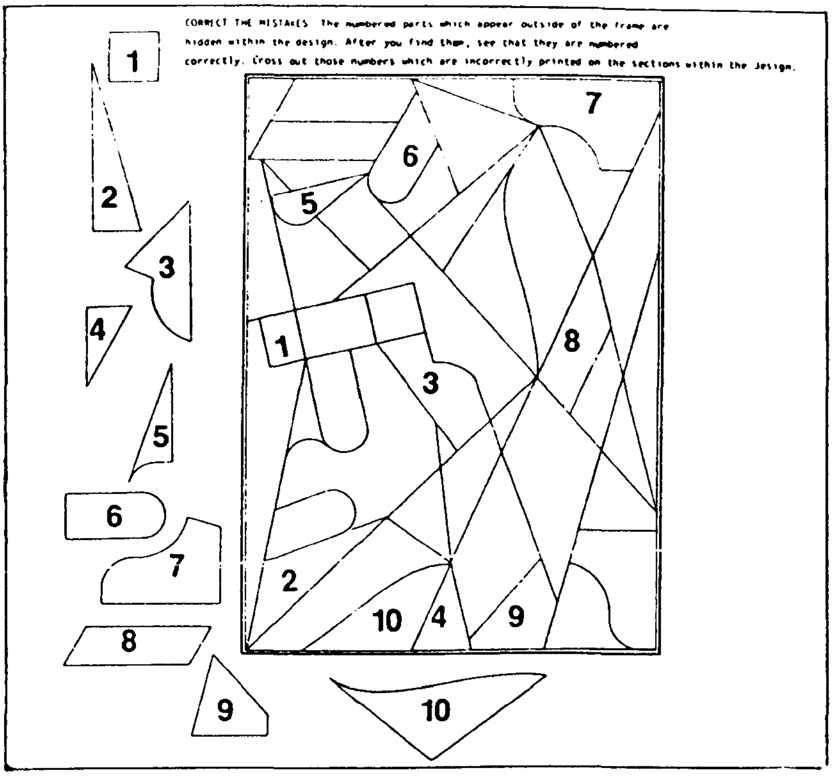
Ibid page 180.



This could also be equated with 'eight words' and 'random pictures' and 'matching row' appendix 3 pages 24, 20 and 21 respectively. Other categories were being used but the underlying process was the same.

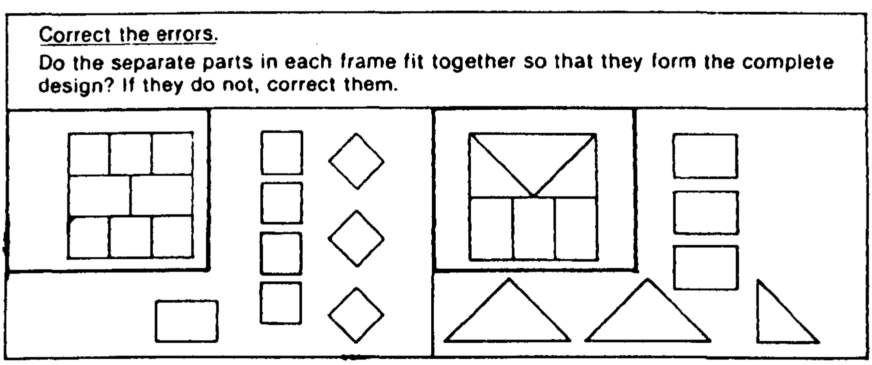
Disembedding/ Analytic perception.

Ibid page 187.



This similar to 'shape in shape' appendix 3 page 26, i.e., that one figure a square or rectangle has to be found in a complex drawing. Embedded figures appendix 3 p. 25 was similar but more difficult because the numbers were not there to help.

Ibid page 188.



This also was similar to 'shape in shape' appendix 3 page 26, i.e., finding what is known within a more complex figure. 'Shape in shape' was more difficult as the figures being looked for overlaid each other.

Thus it is possible to identify similarities in the training materials in this study within Feuerstein's model. The training material in this study contributed a similar function but in a narrower field than Feuerstein's Intrumental Enrichment: they were training for an underlying process not the skills required to pass a particular test. The processes were those that had been identified as being required in the cognitive restructuring aspect of Field-independence. By giving pupils the opportunity to explore and incorporate skills such as: disembedding the simple from the complex; reorganizing information to produce new patterns so breaking up a visual field and recreating it; looking for hidden information systematically; comparison, noting similarities and differences; ignoring irrelevant and confusing material; ignoring basic Gestalt theory of organizing visual field into a coherent whole rather than its constituent parts they would then be able to succeed and show greater Field-independence and consequently Formal Operations. The training materials can be interpreted as substitution for lack of mediation in the development of Field-independent skills in children by parents. The training described in the study was similar therefore in principle to Feuerstein's Mediated Learning Experience, i.e., in that; 1) it did not train for the process itself but for the cognitive function required for the process and 2) substituted for lack of previous mediated experiences to develop those skills.

Although much of what had been done up to this point could be interpreted within the Feuerstein model there was no need to change the training procedures. There was however one aspect of Feuerstein's training that could be incorporated into this study. This was the development of a meta-cognitive language to think with and the 'bridging' of this cognitive development to familiar situations. Feuerstein et al. (1980) contend that unless a subject is aware of the changes in cognition that have been affected by training, and can relate them to similar and familiar situations then it is unlikely that they will be able to use their increased cognitive ability in novel situations. In using his training materials, which are designed to change cognitive functions by substituting for Mediated Learning Experience, teachers are told that at the end of each lesson they need to help the pupils to 'bridge' the concepts developed during the lesson to new contexts. Thus the emphasis is not on the content of the lesson or any particular skill but on the pupils own meta-cognition. Feuerstein's training called Instrumental Enrichment developed cognitive structures using a substitute for natural Mediated Learning Experience, whereas this intervention was in developing the cognitive function of Field-independence. It was felt that emphasising and identifying the meta-cognitive functions of Field-independence and subsequent 'bridging' could enhance the training procedures developed here. Shayer and Wylam (1984) came to a similar conclusion when they helped pupils verbalize the variables involved in their training procedure. The next step was to produce a scheme to develop a meta-cognitive language to enable internalization and a means for mental rehearsal of a list of concepts and strategies with the context of this intervention. The ideas were to come from the pupils, they were not to be imposed by the teacher. The teachers were to emphasise and encourage ideas that were in sympathy with the cognitive process being 'bridged' and to probe and develop relevant examples from inappropriate ones.

Before starting the final study all the materials being used were sorted into three groups those that: 1) emphasised careful comparison; 2) reorganization and; 3) disembedding. The aim was to produce a list with a structure to think with for each of the groups of activities listed above, each list consisting of three single words with brief explanations. The lists were to be created by discussion with the pupils in small groups working with the training materials, identifying the thought processes required by those materials, finding words to express them, and developing explanations in the pupils own words. From these explanations pupils were to list examples where the same processes were used in contexts with which they were familiar. This however was rather open ended and it was felt that some structure was needed to guide other staff. It was therefore decided that the experimenter would work ahead of the other staff and produce a summary of his lessons as a guide. A full explanation of how this was done appears in Chapter 8 and Appendix 4.

Chapter 8: Final study.

INTRODUCTION

In this study there were three experimental groups. One was taken by the experimenter who used training materials and meta-cognitive language, and the other two groups were taken by another teacher who used training materials with both groups but used meta-cognitive language with only one group. There were two control groups taken by other teachers. Once the new materials had been checked, as discussed as in chapter 6, work sheets and equipment were organised, and the other member of staff involved in the training was informed of the principles of the study, i.e., that helping pupils to be more Field-independent would enable them to think at a higher Piagetian level. It was explained that this was to be achieved by incorporating training materials that developed Field-independent skills into the normal science lessons, and in the case of one of his groups by also developing meta-cognitive language. The other teacher involved in the training was shown examples of work the experimenter had done in the feasibility studies. He was informed that most of the materials were integrated into the pupils' normal work and that there was to be no discussion of the purpose of the training materials with the pupils not being trained in meta-cognitive language beyond that necessary to implement them, i.e., organisation, answers to word searches etc. (see first part of appendix 4).

The teacher was asked to spend ten minutes at the beginning or end of lessons working on the materials. The experimenter had regular contact with the other teacher and administrative problems were solved as they arose. There were occasional misunderstandings about what was required but these were minor and easily corrected. When no meta-cognitive language was used implementation was fairly straight forward. Helping *the other member of staff to develop meta-cognitive language with one of his groups was more difficult. By the time of the final study the experimenter had, in the previous summer term, tried out the ideas of developing a meta-cognitive language with a class of children which showed that each section had to be broken down into very small units, using only one or two words in a lesson with a lot of rehearsal and examples to enable 'bridging'.*

The materials were grouped into 3:

Group 1 (developing careful comparison) comprising; 'random pictures', 'matching rows', 'pattern', 'clueless crosswords', 'spot the difference', 'comparison of diagrams and significance of differences',

Group 2 (reorganising) comprising; 'anagrams', 'shuffled sentences', 'sentence gaps', 'random experiments',

Group 3 (disembedding) comprising; 'word searches', 'figures in a dot maze', 'continuo game', 'shape in shape'.

Each of these groups of materials were the basis for discussing a particular strategy for their solutions with the children. Pupils were asked how they went about solving the activities in each group and which mental processes they went through. From this, lists of words that described their thinking were compiled. Pupils were guided, taking one or two words per lesson, with discussion to have a list with meanings and 'bridged examples' of the words that explained how they went about solving the activities within a particular group. The other member of staff was a twenty three year old probationary teacher and it was decided to give him help in implementing the use of meta-cognitive language with teaching notes and edited transcripts of the experimenter's lessons. A complete version of notes, transcripts, and the summary of the transcripts given to the children, are detailed in appendix 4 parts 1, *2 and 3 respectively. Brief extracts from appendix 4 follow. Part 1 are the general teaching notes, part 2 the introductory discussions on group 2 activities and part 3 the edited summary given to the children for that group.*

1)Teaching notes for group 1 activities (developing careful comparison).

A suggested approach for developing a meta-cognitive language to solve problems that require systematic comparison.

1. Ask pupils 'What do you do when trying to solve the activities in group 1'? How do you think? What goes through your mind? What do you do first? How do you sort out what you are looking for? Try to jot the examples down, record them on tape or get individual pupils to write words down on the board or separate paper and collect them afterwards especially those that parallel systematic, careful observation, identify, significant variable, analysis.

2. Group them into three stages: words that describe; 1) analysis, 2) comparison, 3) reflection. Take stage one words and take about ten minutes in the next few lessons to come up with as many simple examples of uses of these words as possible. It is important to emphasise this 'bridging' so that not only do pupils use these words in the context of the activities but can use them or 'see' them used in many different contexts so they not only have a 'dictionary' definition of the word but also a 'feel' for the word's use in a range of examples.

3. Try to get a neat summary of these stage one words to *explain what they were doing, e.g.;*

analysing; combining systematic observation and identification of significant variables,

4. Now repeat the process for stage 2 and 3 words which should be much quicker. When complete you now have a complete definition of the thinking process in solving comparison problems that could go something like this;

Stage 1	*Analysis combines systematic identification and observation of significant variables.*
Stage 2	*Comparison and matching of evidence.*
Stage 3	*Reflecting before answering.*

Pupils could then be asked to try to think of a mnemonic to remember ARC, i.e., Analysis, Comparison, Reflection.

2) Transcript of introductory lesson to group 2 activities (reorganising). Pupils responses are in brackets.

Friday 9th May

We took a long time considering analysing, comparing and reflecting when you were looking at things like spot the difference etc.. Now I want to look at another group of activities you have been doing like anagrams, shuffled sentences, sentences where there are gaps and you have to put the gaps into a different place to get the sentence to make sense, and where I have given you sets of instructions for an experiment and you have had to put them in the correct order. Now if you are trying to solve any one of those what is the first thing you have to try and do?. Lets just take one, anagrams. It might be easier for you to focus your attention on just one of them. What *is the first thing you try and do? (Solve the word). That might be true of a very short word but not of the longer ones. (Groups of letters). Fine! you look for beginnings and endings of words that may make some sense. (Vowels). Yes vowels help you to make some sense out of the jumble of letters. (Try to think of lots of words that contain the same number of letters, then see if any you think of could use the letters you have). Good! that is one way of doing it. Do you always look just at individual letters? (No you put letters together sometimes). When you are looking for a small group of letters that make sense, or vowels, or anything like that I think you could summarise it by saying you look for?.......... (Groups, order, pattern, arrangement, sequence). Great! all those are good words. Which one do you think is best? You are trying to find groups of letters that make some sense. Which of those words do you prefer?. (Majority for pattern). Good you look for patterns of letters that could make some sense so you sort the remaining letters more easily. You are not looking for any letters in particular. You are looking at a jumble of letters, and in them, a pattern that could make sense. Right what do you do with these groups of letters once you've got them? (Sort them). Yes but to sort them you must have done what to the original order of the letters? (Reorganised them). Why do you think I tried to get you to think of what you did before reorganising the letters? (Too difficult). Why? (Short words are easy but lots of letters make it difficult). Why? (It takes too long to reorganise them all ways). Good! You can't reorganise all the letters in all possible combinations until a word comes up that works. Short* *words are fine but longer words would need a computer. So to solve anagrams or similar problems you look for patterns that make sense, reorganise them to see if you can make a word. Then what? What if you don't get a word? (Give up). No come on. (Look at the letters again). What for? (New groups). Yes but what word did we use? (Patterns). Very good! Right that will do for today except try to think before next lesson of examples of where you look for patterns in every day life.*

Examples given by pupils;

cars by variation in patterns, types of buildings, flower types, peoples faces, words, whether things are upright, e.g., buildings, recognise one's own house in a row of similar ones, recognising anything, keys or locks.

3. Complete summary of discussions on group 2 activities.

When solving problems that require reorganization we need to IDENTIFY patterns and REORGANISE them and REPEAT if necessary until a solution is found. Below is a summary of the words you used and examples you gave when explaining what those words meant in describing your thinking about solving 'reorganising' problems.

IDENTIFICATION OF PATTERNS

Examples of the words we used when thinking about identifying patterns were; solve, groups, vowels, letters together, order, pattern, arrangement, sequence, sort, reorganise, look again, new groups.

Examples you gave of where we identify patterns in every day life were; flags of countries, red for danger, piano keyboard, emblem, e.g., rose for England, cars by variation in patterns, computer keyboard, peoples characteristics, e.g., Tom and Jerry, writing characteristics, types of buildings, patterns of letters, e.g., alphabet, logos, known telephone numbers, signatures, known number plates on cars, pop groups that are instantly recognisable, flower types, traffic lights, types of writing, e.g., lists, letters, work cards, television adverts, clothes fashionable or not, medals, people's voices, design diagrams, spelling, e.g., misspelt words, musical notes, map signs, short forms of longer words, e.g., cm., km., word searches, walking and running style.

REORGANISING PATTERNS

Next we tried to find examples of where we reorganise patterns in our lives. The examples you gave were;

1. *The way voices change, e.g., temper, soothing, grumpy etc..*
2. *Changes of tone when motor bikes change gear.*
3. *Plants growing to a set pattern, i.e., seed, plant, flower, seed,*
4. *Aging process in people follows a set pattern,*
5. *Speed bank; patterns of instructions for set outcomes,*
6. *Analogue watch; the hands position is changing all the time,*
7. *Telephone numbers; various codes denote particular areas,*
8. *Writing styles alter as you get older,*
9. *Change in tone of bath water as it fills,*

10. Musical notes make a pattern that can be altered and the music changes,
11. Changing patterns of a computer game, as you do well or not different patterns are produced,
12. Altering words to fit a tune,
13. Speech, dialects etc.,
14. People change clothes but are still recognisable,
15. Changing hair styles,
16. Alphabets in different languages,
17. Changing colours of make up,
18. Spelling mistakes,
19. The same meaning in different languages are usually different words or the same word may have totally different meanings,
20. Changing the tune of a door bell,
21. Transformers (the child type that can be changed from one thing to another, e.g., rocket to robot).

REPEATING

It is necessary to repeat the identification and reorganising of patterns until a solution is found.

The summary you need to remember to solve reorganising problems is;

####################

Identification; of patterns that make some sense,
Reorganisation; of those patterns try to produce a solution,
Repeat; identification and reorganisation until problem is solved.

####################

The complete transcripts are detailed in appendix 4. They were not all given together but were discussed with the probationer lesson by lesson as the experimenter compiled them.

SAMPLE.

Seven mixed ability groups were formed from an intake of 209 first year pupils in a rural comprehensive school. A group of 11 slow learners, identified by Primary school Richmond Test results, (Hieronymus, Lindquist & France, 1975), were removed from the sampling frame. The remaining 198 were divided into seven approximately equal mixed ability groups. The school's policy was to allow friends from primary school to stay together where possible yet keeping the same spread of Richmond test scores in each group. The groups were randomly assigned to members of staff. Although the experimenter had no control over this process no obvious form of bias was identified in the procedures used by the school to assign staff to groups. Five groups took part in the trial: experimental group 1 was given the training materials; experimental groups 2a and 2b were given the training materials and the development of meta-cognitive language; there were two control groups 1c and 2c. Group 2a was taken by the experimenter, groups 1 and 2b by the probationary teacher. Although having a probationer taking two experimental groups was not ideal the experimenter had no control over the process, and it did give him the opportunity of comparing groups with and without meta-cognitive language whilst holding the teacher variable constant. A Kolgromov-Smirnov test was used for the significance of the difference in distribution between experimental groups and the controls, table 8-1.

None of experimental groups showed significant differences from the controls on the measures below.

TABLE 8-1: KOLGROMOV-SMIRNOV TESTS FOR THE SIGNIFICANCE IN DISTRIBUTION BETWEEN EXPERIMENTAL GROUPS AND MERGED CONTROL GROUPS.

	expt. gp1		expt. gp2a		expt. gp2b	
	D	X^2	D	X^2	D	X^2
GEFT	0.10	0.58	0.21	2.90	0.13	1.06
SRTII	0.35	7.07	0.24	3.79	0.34	5.64

D=difference between accumulated proportions between experimental and control and the figure used to test for significance in appendix 6.
None of these reached significance at $p<0.1$
expt.gp.1 N=22, expt.gp.2a N=27, expt.gp.2b, control groups 1c+2c N=42.

METHOD

The five groups taking part in the trial were tested for;

1) Field-independence using the Group Embedded Figures Test (Oltman, Raskin, & Witkin, 1971),

2) Formal Operations using Science Reasoning Task II (NFER, 1979).

Experimental group 1 underwent ordinary exposure to the training materials (see appendix 2 for full description of the materials used). Experimental groups 2a and 2b also underwent the same training but an attempt was made part way through the study to develop a meta-cognitive language in relation to the materials (see appendix 4). The reason for not implementing the use of meta-cognitive language immediately was to give the probationary teacher and children time to become familiar with the materials and their implementation. At the end of the training period pupils were post-tested using the same two cognitive tests (Group Embedded Figures Test, Science Reasoning Task II) plus a specially prepared science test devised by the experimenter in conjunction with other science staff. The latter test was an attempt to find out whether the time used in the lessons on training impeded pupils' science education in terms acceptable to other staff. The null hypotheses being tested in this study were:

1) that after training there would be no significant difference in the mean scores on Field-independence between the experimental groups and the control groups;

2) any increase in Field-independence of the experimental groups over the control groups would not be associated with an increase in Formal Operational level;

3) after training there would be no significant difference in the mean scores for Field-independence between the experimental groups developing a meta-cognitive language and the experimental groups that received training only;

4) after training there would be no significant difference in the mean scores for Formal Operations between the experimental groups developing a meta-cognitive language and the experimental groups that had training only;

5 the experimental groups measured by a written science test, approved by other science staff would be significantly* different from the control groups.

RESULTS.

For ease of presentation and analysis the two control groups were merged and treated as one group of 41. A full set of results for individual groups including means and standard deviations for pre- and post-tests appears in appendix 5. The means and standard deviations of the differences between pre- and post-test scores and are expressed as mean differences in table 8-2.

TABLE 8-2: MEANS AND STANDARD DEVIATIONS FOR POST- MINUS PRE-TEST SCORES ON GROUP EMBEDDED FIGURES AND SCIENCE REASONING TASK II.

		GEFT		SRTII	
Groups	N	$\bar{X}$	σ	$\bar{X}$	σ
Expt. gp1	20	6.75	4.27	0.70	0.87
Expt. gp2a	23	8.17	2.64	1.26	0.86
Expt. gp2b	19	6.58	2.97	1.05	0.52
Control 1+2	41	2.29	2.48	0.32	0.99

Expt. gp1. N=20, Expt. gp.2a N=23, Expt. gp.2b N=19, 1c+2c N=41.

Using MacNemar's procedure as in previous chapters (including test reliability 0.82 for Group Embedded Figures Test and 0.78 for Science Reasoning Task II) one tailed t-tests and Effect sizes were calculated on the differences between pre- and post-test scores on the Group Embedded Figures Test and Science Reasoning Task II between:

1) the experimental groups over the control group; tables 8-3 & 8-4,
2) the experimental groups with meta-cognitive language development (2a & 2b) over experimental group 1 with training only; tables 8-5 & 8-6,
3) the experienced experimenter over the inexperienced probationer; table 8-7.

1. Experimental groups over controls.

TABLE 8-3: t-VALUES ON POST-TEST EXPERIMENTAL OVER CONTROL GROUP DIFFERENCES ON GROUP EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II.

	training but no meta-cog/lang	training with meta-cog/lang.		
Test	expt.gp1	expt.gp2a	expt.gp2b	expt.2a+2b
	t	t	t	t
GEFT	10.20	20.59	12.90	20.67
SRTII	3.30	8.51	8.02	9.42

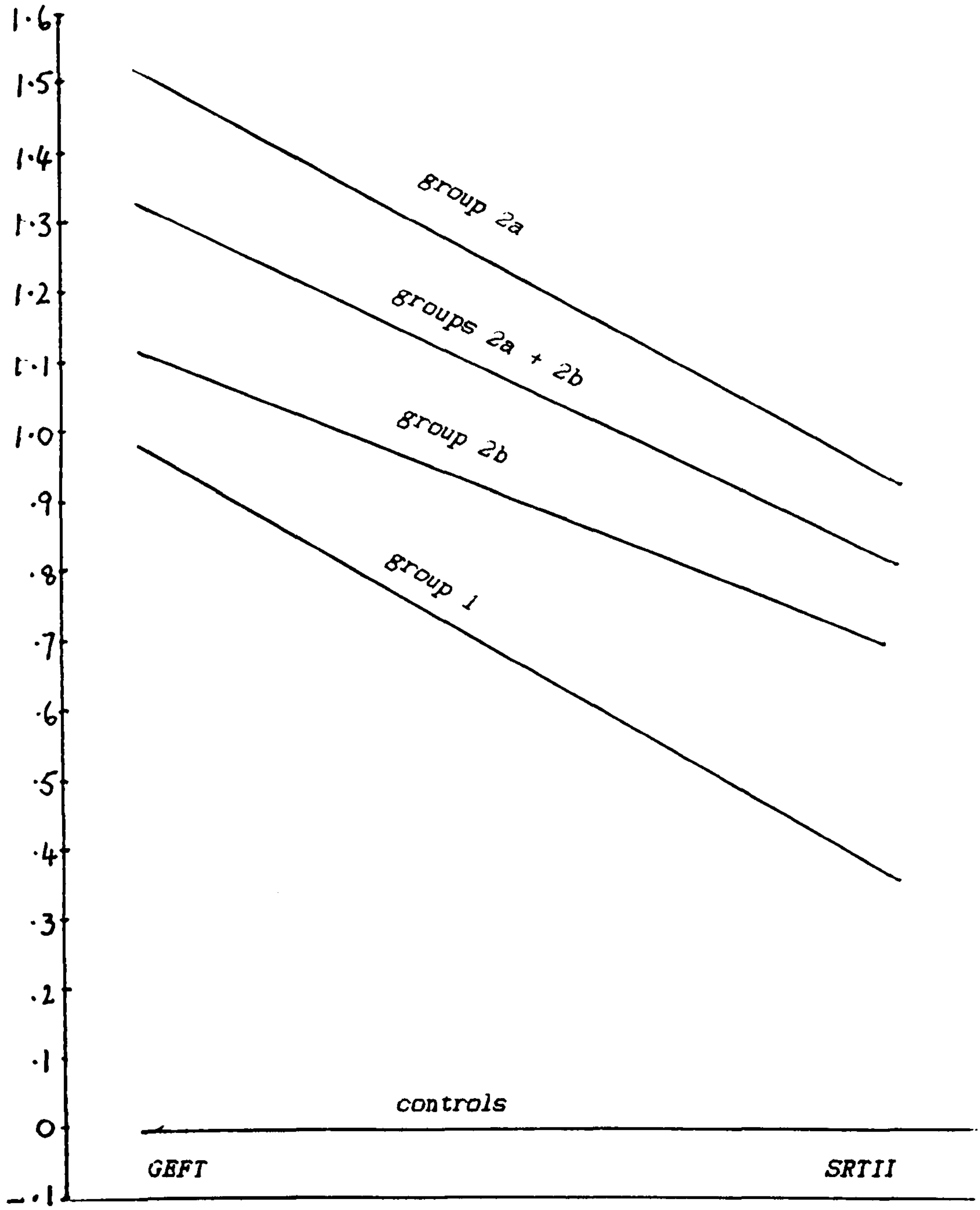
All significant at p<0.0005 except gp1/SRTII significant at p<0.005.
Expt. gp1. N=20, Expt. gp.2a N=23, Expt. gp.2b N=19, 1c+2c N=41.

TABLE 8-4: EFFECT SIZES AND PERCENTILES OF EXPERIMENTAL OVER CONTROLS ON GROUP EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II.

	training but no meta-cog/lang.		training with meta-cog/lang.					
	expt.gp1		expt.gp2a		expt.gp2b		expt.2a+2b	
Test	es	%le	es	%le	es	%le	es	%le
GEFT	1.09	86	1.53	93	1.13	87	1.33	91
SRTII	0.36	64	0.92	82	0.68	75	0.81	79

es=effect size, %le=percentile.
Expt. gp1. N=20, Expt. gp.2a N=23, Expt. gp.2b N=19, 1c+2c N=41.

DIAGRAM 8-1: GRAPH SHOWING EFFECT SIZES OF EXPT. GROUP SCORES OVER CONTROLS ON GROUP EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II.



These results reject the null hypotheses 1 and 2, i.e.;

1) that after training there would be no significant difference in the mean scores on Field-independence between the experimental groups and the control groups;

2) any increase in Field-independence of the experimental groups over the control groups would not be associated with an increase in Formal Operational level;

2. Comparison of experimental groups with meta-cognitive language development (2a & 2b) and experimental group 1 with training only.

TABLE 8-5: t-VALUES BETWEEN EXPT. GPS. 2a & 2b, AND EXPT. GP. 1 ON GROUP EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II.

Test	2a (N=23)		2b (N=19)	
	t	sig.	t	sig.
GEFT	3.04	p<0.005	-0.34	(not sig)
SRTII	4.51	p<0.0005	3.27	p<0.005

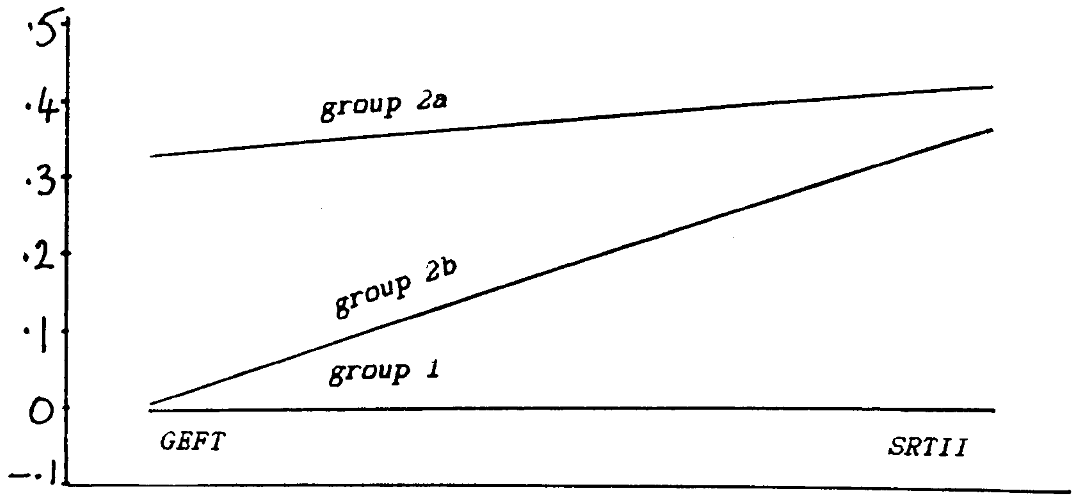
t=t-test, sig.=significance.
Experimental groups 2a & 2b were given meta-cognitive language training.
Experimental group 1 did NOT have meta-cognitive language training.
Expt. gp1. N=20, Expt. gp.2a N=23, Expt. gp.2b N=19.

TABLE 8-6: EFFECT SIZES AND PERCENTILES OF EXPT. GPS. 2a & 2b OVER EXPT. GRP 1 ON EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II

	2a (N=23)		2b (N=19)	
Test	es	%tl	es	%tl
GEFT	0.33	67	0.00	00
SRTII	0.42	66	0.37	64

es=effect size, %le=percentile. Experimental groups 2a & 2b were given meta-cognitive language training. Experimental group 1 did NOT have meta-cognitive language training. Expt. gp1. N=20, Expt. gp.2a N=23, Expt. gp.2b N=19.

DIAGRAM 8-2: GRAPH SHOWING EFFECT SIZES OF EXPT. GRP. 2a & 2b SCORES OVER EXPT. GP 1 ON GROUP EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II.



Null hypothesis 3 has to be accepted, i.e.;

3) after training there would be no significant difference in the mean scores for Field-independence between the experimental groups developing a meta-cognitive language and the experimental groups that received training only.

Null hypothesis 4 can be rejected, i.e.;

4) after training there would be no significant difference in the mean scores for Formal Operations between the experimental groups developing a meta-cognitive language and the experimental groups that received training only;

Null hypothesis 3 is accepted because there were no significant differences in Field-independent development when the teacher variable was held constant, i.e,. group 2b over group 1; although there were significant differences between the experimenter's results i.e. group 2a over group 1. This is contrasted by rejection of null hypothesis 4 where there were significant increases in Formal Operations by groups 2a and 2b over group 1.

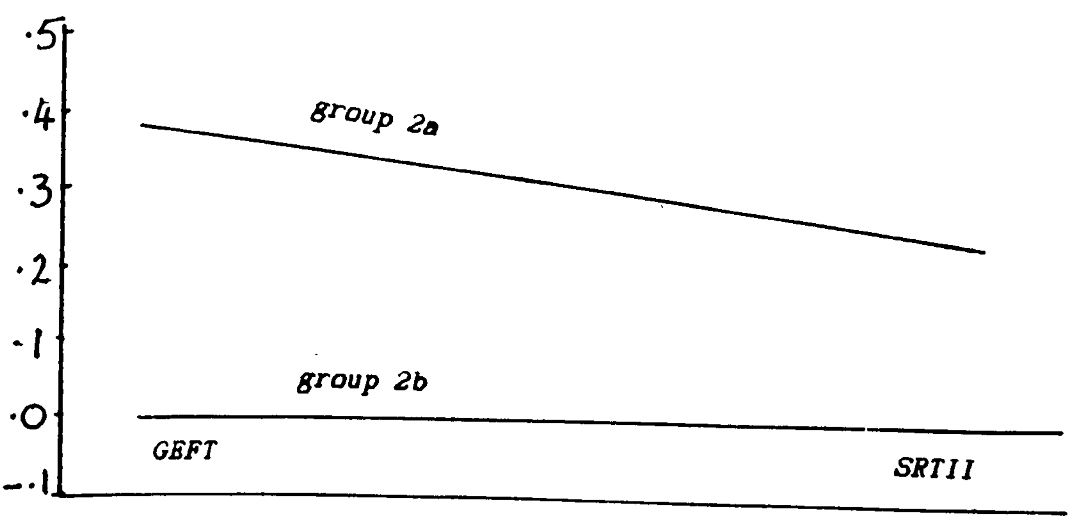
The rejection of null hypothesis 3 led the experimenter to carry out t-tests and effect sizes to establish whether his ability to develop Field-independence and Formal Operations measured by Group Embedded Figures test and Science Reasoning Task II was greater than that of the other teacher involved in the training. Table 8-7 shows that the experimenter was significantly better at developing Field-independence and Formal Operations than the probationary teacher. The most likely explanations are a) the greater teaching experience of the experimenter and b) his greater knowledge and experience in developing what was required to effect the training.

TABLE 8-7: t-VALUES, EFFECT SIZES AND PERCENTILES FOR EXPT. GP. 2a OVER EXPT. GP. 2b.

Test	t	sig.	es	%tl
GEFT	4.28	$p<0.0005$	0.39	65
SRTII	2.08	$p<0.025$	0.23	59

Expt. gp. 2a = experienced teacher Expt. gp. 2b = inexperienced teacher, both used training materials and meta-cognitive language.
Expt. gp.2a N=23, Expt. gp.2b N=19.
es=effect size, %le=percentile, t=t-test, sig.=significance.

DIAGRAM 8-3: GRAPH SHOWING EFFECT SIZES OF EXPT. GRP. 2a SCORES OVER EXPT. GP. 2b ON GROUP EMBEDDED FIGURES TEST AND SCIENCE REASONING TASK II.



Finally t-tests were also calculated on the post-intervention science test.

TABLE 8-8: t-VALUES ON POST-TEST EXPERIMENTAL OVER CONTROL GROUP DIFFERENCES ON POST INTERVENTION SCIENCE TEST.

training but no meta-cog/lang		training with meta-cog/lang.			
expt.gp1		expt.gp2a		expt. gp2b	
t	sig.	t	sig	t	sig
2.29	$p<0.025$	0.85	not sig.	0.48	notsig

t=t-test, sig.=significance.
Expt. gp1. N=20, Expt. gp.2a N=23, Expt. gp.2b N=19, 1c+2c N=41.

These reject null hypothesis 5, i.e.;

5) the experimental groups measured by a written science test, approved by other science staff would be significantly different than the control groups.

In fact all did marginally better, one significantly so.

DISCUSSION.

Effect sizes and t-test results showed significant increases over controls have taken place in all groups undergoing training in the cognitive restructuring aspect of Field-independence measured by the Group Embedded Figures Test (Groups 1, 2a, 2b and 2a+2b all significant at least $p<0.0005$ with effect sizes of 1.09, 1.53, 1.13 and 1.33 respectively). This study therefore not only showed as with the previous studies that it was possible to develop this aspect of Field-independence but that these training materials could be used by inexperienced teachers and easily incorporated into science lessons. There were also significant gains in all groups over controls in Formal Operations measured using

Science Reasoning Task II (group 1a at $p<0.005$ and 2a, 2b and 2a+2b at $p<0.0005$ with effect sizes of 0.36, 0.92, 0.68 and 0.81 respectively). It is therefore concluded that development of Field-independence has a positive and significant influence over cognitive development measured by Science Reasoning Task II, even when used by an inexperienced teacher. A diagrammatic representation after, Rosenthal (1978) and Smith & Glass (1977, 1981) using effect sizes can be seen in appendix 5 diagrams 1-4 for groups 1 and 2a+2b on the Group Embedded Figures Test and Science Reasoning Task II. The size of the increase in the cognitive restructuring aspect of Field-independence when meta-cognitive language is developed is less clear. Within this study group 1 without meta-cognitive language and 2b with meta-cognitive language were taken by the same teacher. If these groups are compared the effect of using meta-cognitive language to enhance Field-independence appeared unsuccessful i.e. $t= -0.3416$ and not significant. If these groups are compared for the effect of meta-cognitive language on the development of Formal Operations then there was a significant increase, i.e., $p<0.005$ with a effect size of 0.37. Within this study the use of meta-cognitive language has not had the effect of increasing the effectiveness of training on Field-independence measured by Group Embedded Figures Test but has had an effect on cognitive development measured by Science Reasoning Task II when the teacher variable is held constant. If however the experimenter's results in this study (group 2a), where meta-cognitive language was used, are compared with his previous studies, i.e., feasibility studies 1 and 2 where meta-cognitive language was not used then use of meta-cognitive language has had a significant effect on Field-independence training and subsequent Formal Operational development. This is argued by comparing those with the highest effect sizes over controls the experimenter produced in previous studies, i.e., 0.92σ compared with 1.53σ for Group Embedded Figures Test and 0.74σ compared with 0.92σ for Science Reasoning Task II.

A one tailed t-test on increases produced by the experimenter using meta-cognitive language in this study over the best results when meta-cognitive language was not used in previous studies was significant ($t=8.6$ $p<0.0005$ for Group Embedded Figures Test and $t=2.6$ $p<0.025$ for Science Reasoning Task II). The problem with this interpretation is that when the effect of meta-cognitive language was removed the training itself differed; 1) less time was spent each lesson but more was spent overall and therefore more time was spent on task, 2) the control groups were different (although all significant gains were still valid even if the feasibility studies' control groups means and standard deviations were used) and 3) the training materials were integrated into the work rather than treated separately.

Because of the differences in training between studies it was not possible to use analysis of variance to isolate these effects as one square of the matrix was always confounded. If for illustrative purposes I1 was the non meta-cognitive language training undertaken by the experimenter in previous studies, I2 non meta-cognitive language in this study, I3 meta-cognitive language used in this study T1 the experimenter and T2 the teacher who took both types of intervention in this study then the matrix looks as follows.

	I1	I2	I3
T1	*		*
T2		*	*

I1 and I2 were similar but were not the same although the experimenter claims that gains he developed using meta-cognitive language over previous studies where he did not, are meaningful. The results show that inexperienced teachers can use these materials and produce significant increases in Field-independence and Formal Operational development. Use of meta-cognitive language when used by an inexperienced teacher appears to aid transfer of training. When meta-cognitive language is used by an experienced teacher there is evidence to suggest that it does increase the effectiveness of the training itself. It is therefore suggested that the use of meta-cognitive language by an inexperienced teacher compensates for what most experienced teachers do anyway but if the results of the feasibility studies are considered, meta-cognitive language may be considered as helping to enhance the training when used by an experienced teacher. This claim is supported by the experimenter producing significant gains over the inexperienced teacher ($p<0.0005$ for Group Embedded Figures Test and $p<0.05$ for Science Reasoning Task II) within this study. This was achieved even though the inexperienced teacher was using detailed notes for classroom implementation prepared by the experimenter (i.e., as near as is possible within classroom situations the inexperienced teacher gave the same lessons in meta-cognitive language training as the experimenter). The greatest gain the experimenter produced over the inexperienced teacher was in the Field-independence training, i.e., the aspect the meta-cognitive language was designed to increase. It is concluded therefore that;

1) materials used on their own produced significant gains in Field-independence and Formal Operations whether the teacher is experienced or not,

2) use of meta-cognitive language with an inexperienced teacher did

not enhance training but appeared to aid transfer of training,

3) *use of meta-cognitive language with an experienced teacher not only significantly enhanced the training over its implementation with an inexperienced teacher but also significantly increased the cognitive development of pupils beyond that produced by an inexperienced teacher.*

A full 2 factor design would be needed to confirm this, i.e., to show that experienced teachers always produce significant gains over inexperienced teachers and that inexperienced teachers using meta-cognitive language increase cognitive development in pupils rather than enhancing the training. It had been suggested by some more staff who were intuitively sceptical of the training procedures that the training was not only a waste of time but would impede the pupils' progress in science. A science test was given at the end of the training period to show that this was not the case. The test was compiled by the experimenter, circulated, modified, and the modified version approved by all first year staff as being suitable for testing things they thought valid before being given to the pupils. All experimental groups showed increases over controls although only group 1 showed a significant increase. Pupils being trained were not disadvantaged by not being given 'proper science teaching' but in fact gained by developing both Field-independent skills and also Formal Operations.

Chapter 9: Conclusions.

In Chapter 1, the introduction, the aims and philosophy of the thesis were outlined as follows. Piaget's model of cognitive development had been widely accepted. The highest level, i.e., that of Formal Operations is implicit in 'scientific method' and much science curricula. It is a sophisticated approach that approximately only thirty percent of the population ever reach. Developing Formal Operations would therefore be a valuable contribution to education in general and science teaching in particular. Most attempts at training had tried to develop Formal Operational skills, and had not been very successful. It had been shown that Formal Operations was positively correlated to the cognitive style of Field-independence. Field-independence is made up of two parts;

a) perception

b) cognitive restructuring.

Training in the perceptual aspect had been tried and shown to be unsuccessful. The cognitive restructuring of information seemed an obvious prerequisite to being able to perceive and manipulate variables in a Formal Operational task and therefore any increase in this contributory skill should have developed a higher level of Formal Operational thought. In Chapter 2 part 5 the outline of the thesis was stated as follows; Field-dependence/independence is a cognitive style that identifies a subject's ability to identify the single significant item from a field of confounding information. Part of Formal Operations requires control of variables. If subjects are not Field-independent then it would unlikely that they were going to be able to isolate the significant variables in problems even if they had the mental capacity to manipulate those variables in a Formal Operational way. As only about 30% of 15/16 year olds ever reach Formal Operations (Shayer, 1980 and Shayer & Wylam, 1978), much of science teaching may be conceptually too *difficult for many pupils. Therefore aiding pupils to develop Field-independence and consequentially Formal Operations, is an important adjunct not only to science education but also to the pupils' personal development. Formal Operational thought is not just of use to science, although it may exhibit its most obvious manifestation there. It is a powerful cognitive tool applicable to many other spheres of learning especially at their higher levels. If its development can be achieved by training in Field-independence then this would also be accompanied by the skills: careful comparison, reorganization and restructuring of information, isolation of the particular from the general and disembedding of confounding or overlapping information. These skills are important in their own right.*

The thesis has shown that although it was not possible to train for the perceptual aspect of Field-independence, (Morell, 1976) it has been possible to train for the cognitive restructuring aspect of Field-independence. The experimenter could find no previous attempt, successful or otherwise at this. This training can be accomplished by carrying out activities that give practise in the six points identified by the experimenter as the skills necessary to be Field-independent;

1) *disembedding the simple from the complex,*
2) *reorganizing information to produce new patterns so breaking up a visual field,*
3) *looking for hidden information systematically,*
4) *comparison, noting differences and similarities,*
5) *ignoring irrelevant and confusing material,*
6) *ignoring basic Gestalt theory of organising visual field into a coherent whole rather than its constituent parts.*

It would seem unlikely that scientific thought is possible without the observational skills inherent in the cognitive restructuring aspect of Field-independence. The pilot study, (Chapter 3) and the three subsequent studies, (Chapters 4, 5 and 8) confirmed this with significant gains in Field-independence measured by the Group Embedded Figures Test. These gains also had a significant positive effect on pupils' Formal Operational development. There was no way in which the training carried out in Field-independence could be interpreted as training in Formal Operations yet there were substantial gains in Formal Operations in all the studies undertaken. The gains have not been as great as those of Field-independence but these studies confirmed the close association between these two measures. Linn & Swiney's model (Chapter 2) suggested that only 12% of the variance on formal operational measures could not be explained by their model which combined crystallized ability, cognitive restructuring and familiar field. The results of this thesis are interpreted as demonstrating that the cognitive restructuring aspect of this model could be developed and this had a substantial and significant effect on Formal Operations.

It could be argued that the type of training undertaken could develop general ability rather than Field-independence in particular. This was contradicted by Feasibility study 2 (Chapter 5) which confirmed Satterley's hypothesis that cognitive style and in particular Field-independence did not overlap with general ability. This study showed significant gains in Field-independence and Formal Operations but minimal gains in the scores on Cognitive Abilities Tasks, a measure of general ability. This demonstrated that measuring Field-independence and Formal Operations was as important as measuring general ability. It is possible *to reason scientifically measured by Science Reasoning Task II but perform badly on a test of general ability, i.e., Cognitive Abilities Tasks. The study showed that it was possible for members of staff other than the experimenter to produce a comparable, though smaller effect using the same materials.*

Influenced by Feuerstein et al. (1980) the final study (Chapter 8) introduced the aspect of meta-cognitive language in an attempt to enhance the effectiveness of the training materials. This was one of the training procedures Feuerstein et al. developed to enhance his own training substituting for Mediated Learning Experience. Feuerstein et al. suggested that lack of social transmission or of Mediated Learning Experience was often what made children perform at a level lower than that of which they were cognitively capable. It was proposed in Chapter 7 that these training materials were similar to some of Feuerstein et al. in that they substituted for the 'care-giver' in mediating or selecting only relevant information for the child to consider from the environment. Although this was only one aspect of a much larger study by Feuerstein et al. the critical selection aspect of these training materials could be interpreted within Feuerstein's terms. Piaget (1964) suggested four factors that influenced the development of Formal Operations: maturation, experience, social transmission and equilibration. The main factor of interest was social transmission. This thesis is interpreted as giving support to the hypothesis that those that are Field-independent have had experiences, probably from their care-giver or general environment, that develop critical selection of information from a confusing field of irrelevant information. It is suggested that one of the aspects Feuerstein et al. was trying to develop was very similar to that being developed in this thesis, i.e., to give experience in the procedures necessary for critical selection of relevant information from a disorganised field of information. It was this selection of the significant variables that the experimenter identified as a reason why some pupils while having the potential mental capacity to solve Formal Operational problems could not do so. It is suggested that these training materials gave practice in these critical selection skills and were substituting lack of an aspect of Mediated Learning Experience.

There were parallels between some aspects of Feuerstein's major goal of increased modifiability and Field-independence, and the training materials Feuerstein et al. used to develop pupils' accommodation to reality and the training materials the experimenter was using to develop Field-independence. Since use of meta-cognitive language was instrumental in Feuerstein's training, it may also have enhanced the Field-independence training. The training procedure was taken from Feuerstein et al. (1980) and detailed in Appendix 4. The training was designed to help pupils conceptualize their thinking about the way they tackled the Field-independence training materials. Lovell (1979) identified one of Piaget's contributions of lasting value as distinguishing 'The cognisance, or act of becoming conscious of an active scheme (i.e., of a repeatable and generalizable action), or of an internalized scheme for that matter, is a pre-requisite for generalizations and for tackling new problems in which the same strategies are involved', as an important aspect of higher thought. It was this aspect of thinking about thinking identified by Piaget and Feuerstein that prompted use of meta-cognitive language.

Firstly this final study confirmed the feasibility studies, i.e.;

1) that the cognitive restructuring aspect of Field-independence could be developed by training,

2) that increases in Field-independence were associated with gains in Formal Operations.

In addition the study showed that;

3) the materials could easily be integrated into existing courses,

4) the materials could be used easily by teachers other than the experimenter, even probationers, and still produce significant effects,

5) the time taken using the material had no detrimental effects on the development of pupil's proper science defined by other staff,

6) the use of meta-cognitive language had a positive and beneficial effect on the cognitive development of pupils.

This last point is complex and is discussed fully in the previous chapter. Briefly however;

1) use of the materials on their own, produced significant gains in Field-independence and Formal Operations whether teachers were experienced or not,

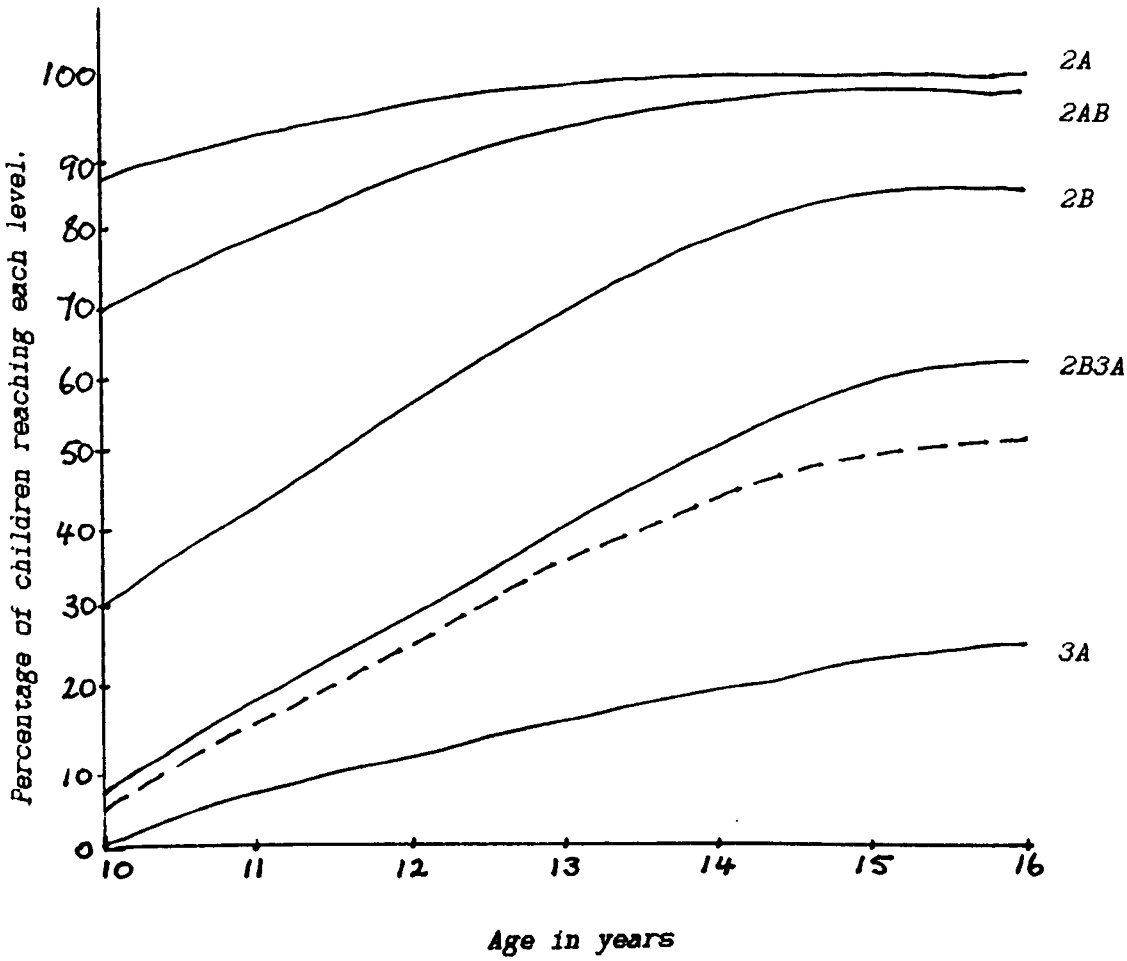
2) use of meta-cognitive language with an inexperienced teacher did not enhance the Field-independence training but assisted <u>transfer</u> of training so as to help pupils' cognitive development,

3) use of meta-cognitive language with an experienced teacher not only significantly enhanced the training over its implementation with an inexperienced teacher but also significantly increased the cognitive development of pupils beyond that produced by an inexperienced teacher.

The main conclusions of the thesis are that if pupils are to tackle tasks requiring Formal Operational thinking they do so much better if they are more Field-independent and that Field-independence can be improved by training materials. The training materials were a legitimate activity in a science classroom and the time taken did not impair performance on a class test endorsed by all staff. The materials required a change of emphasis rather than any radical change in content or teaching style. Field-independence does not overlap with general ability, and, as with Formal Operations, should be assessed in addition to any tests of general ability. The use of the training materials can be seen as substituting for lack of the 'selection of significant criteria' aspect of Instrumental Enrichment. Meta-cognitive language was used in the hope of enhancing teachers' Field-independence training but produced unclear results. Medtacognitive Language helped an inexperienced teacher to significantly increase the cognitive development of pupils measured by Science Reasoning Task II, but not by enhancing the training of Field-independence, and there was evidence to indicate that the use of meta-cognitive language had a positive and significant effect in improving the Field-independence training measured by Group Embedded Figures Test with the experimenter.

Shayer & Adey (1981) showed that development of early Formal Operations, i.e., 3A was necessary to pass science examinations in the General Certificate of Education or to gain grades 1,2 or 3 on the new General Certificate of Secondary Education particularly from year 3 (14-15 year olds) onwards. A prediction of the number of extra pupils that could pass these examinations having undergone training was used as a measure of how successful the training had been. The percentage of pupils *reaching each Piagetian level was calculated from the survey by Shayer & Wylam (1978) table 3, p.64. These were plotted on a graph, diagram 9-1 to establish a direct comparison with the average age of sample in the final study. The pre-test results using all experimental and control groups (N=103) at average age 11 years 5 months is given in table 9-1.*

DIAGRAM 9-1: DISTRIBUTION OF PIAGETIAN LEVELS IN BRITISH SCHOOL CHILDREN, ADAPTED FROM SHAYER & WYLAM (1978).



------ = estimate of quarter distance between Piagetian levels 2B3A and 3A

TABLE 9-1: COMPARISON BETWEEN SHAYER & WYLAM (1978) SURVEY AND FINAL STUDY, OF THE PERCENTAGE OF CHILDREN REACHING EACH PIAGETIAN LEVEL AT 11 YEARS 5 MONTHS.

	Piagetian Levels					
	1	2A	2A2B	2B	2B3A	3A
S&W survey	100	94	85	53	26	8
Final study	100	94	85	43	7	0

S&W survey N=7093, Final study all groups N=103.

Table 9-1 shows that the distribution of children used in the final study did not match Shayer & Wylams' survey at the higher levels, confirming the experimenter's original concern that pupils in the school were substantially below average. Next the proportions at post-test, i.e., age 12 years 5 months, of the experimental groups and control groups reaching the various Piagetian levels were compared, (table 9-2).

TABLE 9-2: COMPARISON BETWEEN SHAYER & WYLAM (1978) SURVEY AND FINAL STUDY, OF THE PERCENTAGE OF CHILDREN REACHING EACH PIAGETIAN LEVEL IN EXPERIMENTAL AND CONTROL GROUPS AT 12 YEARS 5 MONTHS.

	Piagetian Levels					
	1	2A	2A2B	2B	2B3A	3A
S&W survey	100	97	89	64	37	13
Expt.gps.2a+2b	100	100	100	90	50	24
Expt.gp.1	100	100	100	80	45	10
Controls 1c+2c	98	85	73	46	9	2

S&W survey N=7093, Expt.gps. 2a+2b N=42, Expt.gp. 1 N=20, Control 1c+2c N=41

Table 9-2 shows that training with meta-cognitive language increased the number of 3A pupils from two in control groups to twenty four. When no meta-cognitive language was used the increase was ten, i.e. eight over controls but still below the national average. Although the concern here was with 3A pupils it is noteworthy that in all the other Piagetian levels the increases went from below to above the national survey average during the time of training, whether the pupils had meta-cognitive language training or not. The controls remained consistently below the national average. With increases at the levels below 3A it was reasonable to assume that a proportion of these were likely to reach 3A by the time they took GCE or GCSE. To gain some estimate of this it was necessary to use the Shayer & Wylam survey to establish the minimum level above which students needed to be at twelve years five months to be at 3A at fifteen years nine months when they took the examinations. From the national survey 25% of pupils were at 3A at fifteen years nine months. When extrapolated it was found that pupils needed to be about a quarter of the way between 2B/3A and 3A at twelve years five months. Using Figure 9-1 it was found that some 30% of pupils were at that level at twelve years five months, thus about 0.83 of pupils at just over 2B/3A at twelve years five months will be at least at 3A by the time they reach fifteen years nine months. Before the proportion could be applied to the number of extra pupils who were at this stage as a result of training it was necessary to estimate how many there were as there were no direct figures for these pupils, i.e., who were between stages above 2B/3A but had not reached 3A. Using the Shayer and Wylam survey 81% of pupils at twelve years five months who were at at least 2B/3A were also a quarter of the way to 3A. This meant that 0.81 of the 50% of pupils at 2B/3A as a result of training and use of meta-cognitive language (i.e., 40%) were likely to have been a quarter of the way to being 3A. Out of this 40% 0.83 were likely to become 3A by the time they reached fifteen years nine months, (i.e., 33%). The survey showed that 25% would have developed to 3A by this age without training leaving 8%.

When this 8% was added to the extra 24% who had become 3A directly as a result of training this gave an increase of 32% of pupils in the school who should be at 3A by the time they reached fifteen years nine months and capable of GCE or GCSE grade 1,2 or 3 passes. When the same process was applied to training where no meta-cognitive language was used then 15% increase was found.

These figures are highly speculative and there is no guarantee that the training is permanent. The training takes up a proportionally smaller proportion of total learning experience as the child ages and many of the figures are estimates. The training procedures produced important gains at all Piagetian levels and there is no reason why the emphasis should not be continued throughout secondary science curriculum provided the teaching utilizes the enhanced thinking. There was no change in content, simply a change in emphasis. When only training materials were used the emphasis was on Field-independent skills; when used in conjunction with use of meta-cognitive language the extra dimension of giving language to thought processes and bridging these to familiar examples was developed. These skills could be developed by any science teacher and could easily become part of their teaching strategy and so capitalize upon pupils' Field-independent skills and consequently Formal Operations. Development of Field-independence is an important development in its own right helping pupils to;

1) disembed the simple from the complex,
2) re-organize information to produce new patterns so breaking up a visual field,
3) look for hidden information systematically,
4) compare, noting differences and similarities,
5) ignore irrelevant and confusing material,

6) ignore basic Gestalt theory of organising visual field into a coherent whole rather than its constituent parts.

This thesis has shown that development of these skills has a significant and positive effect on the development of Formal Operations and consequently develops the skills noted by Selly (1981):

1) develop systematic analysis of problems,
2) suggest possible solutions to problems,
3) understand reliability of evidence,
4) develop awareness of errors, degrees of confidence,
5) develop scientific scepticism and detect bias,
6) appreciate the difference between opinion and fact,
7) develop the ability to test hypothesis,

and UNESCO (1980);

1) reason without directly referring to concrete objects,
2) draw conclusions from statements which are possibilities and not merely observations of reality,
3) he can deal with relation between relations such as proportions,
4) when several variables are considered he is not restricted to dealing with them one at a time,
5) he can experimentally or mentally cancel out the effect of all other factors, while systematically varying one to determine its effect.

These are powerful and necessary skills to deal with our increasingly technical society and the increasing demands of science curricula in schools. If pupils can develop Field-independence by use of the ideas behind the materials detailed in Appendix 3 and in essence are developing critical selection skills, and this in turn develops Formal Operations *then not only will pupils become more observant but also more able to deal with the complexities of science and other subject areas. If teachers can show a corresponding change in the degree to which they ask pupils to use such cognitive skills in their learning of science, then it would be reasonable to expect the enhanced achievement at GCSE science extrapolated from the findings of this study.*

Appendix 1: Feasibility Study 1; Calculations.

The Kolgromov-Smirnov test for the significance of the difference of distribution between the experimental and control group on Group Embedded Figures and Science Reasoning Task II. See appendix 6 for table of significance using D after Guilford (1973, page 226).

Group Embedded Figures Test

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
0- 2	2	3	2	3	0.01	0.14	0.13
3- 5	2	4	4	7	0.02	0.33	0.13
6- 8	7	7	11	14	0.55	0.66	0.11
9-11	3	3	14	17	0.70	0.80	0.10
12-14	3	3	17	20	0.85	0.95	0.10
15-17	3	1	20	21	1.00	1.00	0.00

therefore D=013: $\chi^2 = 4(0.13)^2 \dfrac{(20 \times 21)}{(20 + 21)}$

$= 0.6924$ which is not significant at $p<0.10$

Science Reasoning Task II

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
1	3	5	3	5	0.15	0.24	0.09
2	8	3	11	5	0.55	0.38	-0.17
3	8	8	19	16	0.80	0.76	-0.04
4	1	5	20	21	1.00	1.00	0.00
5	0	0	20	21	1.00	1.00	0.00

therefore D= 0.169: $\chi^2 = 4(0.169)^2 \dfrac{(20 \times 21)}{(20 + 21)}$

$= 1.1703$ which is not significant at $p<0.10$

Appendix 2: Feasibility study 2; Results.

Kolgromov-Smirnov tests for the significance of the difference in distribution between two groups

Group Embedded Figures Test

TABLE APPENDIX 2-1: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.1 AND CONTROL GROUP ON GROUP EMBEDDED FIGURES TEST.

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
0- 2	5	3	5	3	0.29	0.16	0.13
3- 5	6	5	11	8	0.64	0.42	0.22
6- 8	4	4	15	12	0.88	0.63	0.25
9-11	1	6	16	18	0.94	0.94	0.00
12-14	1	1	17	19	1.00	1.00	0.00
15-17	0	0	17	19	1.00	1.00	0.00

therefore D=0.25: $\chi^2 = 4(0.25)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 2.2425 which is not significant at $p<0.10$

TABLE APPENDIX 2-2: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.2 AND CONTROL GROUP ON GROUP EMBEDDED FIGURES TEST.

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
0- 2	5	3	5	3	0.29	0.16	0.13
3- 5	4	5	9	8	0.52	0.42	0.10
6- 8	4	4	13	12	0.76	0.63	0.13
9-11	2	6	15	18	0.88	0.94	0.06
12-14	0	1	15	19	0.88	1.00	0.12
15-17	2	0	17	19	1.00	1.00	0.00

therefore D=0.13: $\chi^2 = 4(0.13)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.6063 which is not significant at $p<0.10$

Science Reasoning Task II

TABLE APPENDIX 2-3: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.1 AND CONTROL GROUP ON SCIENCE REASONING TASK II.

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
1	1	0	1	0	0.05	0.00	0.05
2A	0	1	1	1	0.05	0.05	0.00
2A/2B	6	7	7	8	0.41	0.42	-0.01
2B	7	9	14	17	0.82	0.89	-0.05
2B/3A	3	2	17	19	1.00	1.00	0.00
3A	0	0	17	19	1.00	1.00	0.00

therefore D= 0.05: $\chi^2 = 4(0.05)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.0897 which is not significant at $p<0.10$

TABLE APPENDIX 2-4: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.2 AND CONTROL GROUP ON SCIENCE REASONING TASK II.

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
1	0	0	0	0	0.00	0.00	0.00
2A	0	1	0	1	0.00	0.05	0.05
2A/2B	5	7	5	8	0.29	0.42	0.13
2B	10	9	15	17	0.89	0.89	0.00
2B/3A	2	2	17	19	1.00	1.00	0.00
3A	0	0	17	19	1.00	1.00	0.00

therefore D= 0.13: $\chi^2 = 4(0.13)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.6063 which is not significant at $p<0.10$

TABLE APPENDIX 2-5: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (VERBAL).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	2	1	2	1	0.12	0.05	0.07
93-105	8	7	10	8	0.59	0.42	0.17
106-118	4	6	14	14	0.85	0.73	0.12
119-131	2	5	16	19	0.94	1.00	0.06
132-144	1	0	17	19	1.00	1.00	0.00

therefore D= 0.17: $\chi^2 = 4(0.17)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 1.037 which is not significant at p<0.10

TABLE APPENDIX 2-6: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (VERBAL).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	2	1	2	1	0.12	0.05	0.07
93-105	4	7	6	8	0.35	0.42	0.07
106-118	9	6	15	14	0.88	0.73	0.15
119-131	1	5	16	19	0.94	1.00	0.06
132-144	1	0	17	19	1.00	1.00	0.00

therefore D= 0.15: $\chi^2 = 4(0.15)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.088 which is not significant at p<0.10

TABLE APPENDIX 2-7: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (QUANTITATIVE).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	1	4	1	4	0.05	0.21	0.16
93-105	3	4	4	8	0.23	0.42	0.19
106-118	8	10	12	18	0.70	0.94	0.24
119-131	2	0	14	18	0.82	0.94	0.12
132-144	3	1	17	19	1.00	1.00	0.00

therefore D= 0.24: $\chi^2 = 4(0.24)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 2.066 which is not significant at $p<0.10$

TABLE APPENDIX 2-8: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (QUANTITATIVE).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	2	4	2	4	0.11	0.21	0.10
93-105	3	4	5	8	0.29	0.42	0.13
106-118	7	10	12	18	0.70	0.94	0.24
119-131	5	0	17	18	1.00	0.94	0.06
132-144	0	1	17	19	1.00	1.00	0.00

therefore D= 0.24: $\chi^2 = 4(0.24)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 2.066 which is not significant at $p<0.10$

TABLE APPENDIX 2-9: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (NON VERBAL).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	2	2	2	2	0.12	0.11	0.01
93-105	4	7	6	9	0.35	0.47	0.12
106-118	5	4	11	13	0.65	0.76	0.11
119-131	5	4	16	17	0.94	0.89	0.05
132-144	1	2	17	19	1.00	1.00	0.00

therefore D= 0.12: $\chi^2 = 4(0.12)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.5166 which is not significant at p<0.10

TABLE APPENDIX 2-10: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (NON VERBAL).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	1	2	1	2	0.05	0.11	0.06
93-105	5	7	6	9	0.35	0.47	0.12
106-118	7	4	13	13	0.76	0.76	0.08
119-131	4	4	17	17	1.00	0.89	0.11
132-144	0	2	17	19	1.00	1.00	0.00

therefore D= 0.12: $\chi^2 = 4(0.12)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.5166 which is not significant at p<0.10

TABLE APPENDIX 2-11: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (AVERAGE).

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	1	2	1	2	0.05	0.11	0.06
93-105	6	6	7	8	0.41	0.42	0.01
106-118	6	7	13	15	0.76	0.79	0.03
119-131	3	4	16	19	0.94	1.00	0.06
132-144	1	0	17	19	1.00	1.00	0.00

therefore D= 0.06: $\chi^2 = 4(0.06)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.1292 which is not significant at p<0.10

TABLE APPENDIX 2-12: SIGNIFICANCE OF DISTRIBUTION BETWEEN EXPT. GP.2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASKS (AVERAGE)

scores	f		cf		cp		diff
	expt.	con.	expt.	con.	expt.	con.	
80- 92	2	2	2	2	0.11	0.11	0.00
93-105	3	6	5	8	0.29	0.42	0.13
106-118	7	7	12	15	0.71	0.79	0.08
119-131	5	4	17	19	1.00	1.00	0.00
132-144	0	0	17	19	1.00	1.00	0.00

therefore D= 0.13: $\chi^2 = 4(0.13)^2 \frac{(17 \times 19)}{(17 + 19)}$

= 0.6063 which is not significant at p<0.10

TABLE APPENDIX 2-13: MEANS AND STANDARD DEVIATIONS FOR PRE- AND POST-TEST SCORES ON GROUP EMBEDDED FIGURES TEST, SCIENCE REASONING TASK II AND THE COGNITIVE ABILITIES TASKS.

		Pre test		Post test		Difference pre-post test	
	N	$\bar{X}$	θ	$\bar{X}$	θ	$\bar{X}_2-\bar{X}_1$	θ
Group Embedded Figures Test							
Expt. gp 1	17	4.53	3.36	9.71	3.70	5.18	2.48
Expt. gp 2	17	5.65	4.60	11.23	3.63	5.59	2.50
Control	19	6.11	3.30	7.95	4.08	1.84	2.75
Science Reasoning Task II.							
Expt. gp 1	17	2.67	1.00	3.46	1.01	0.82	0.95
Expt. gp 2	17	2.83	0.63	3.59	0.62	0.76	0.75
Control	19	2.68	0.67	2.90	0.57	0.21	0.79
Cognitive Abilities Tasks (verbal)							
Expt. gp 1	17	108.24	12.72	115.12	15.50	7.12	10.46
Expt. gp 2	17	109.29	11.67	112.26	12.50	2.94	8.89
Control	19	109.68	10.07	115.37	11.47	5.68	7.30
Cognitive Abilities Tasks (quantitative)							
Expt. gp 1	17	106.41	27.03	113.41	16.85	7.00	22.49
Expt. gp 2	17	112.06	12.60	113.18	13.22	1.12	8.40
Control	19	103.53	11.67	108.42	16.76	4.90	13.52
Cognitive Abilities Tasks (non-verbal)							
Expt. gp 1	17	111.12	16.57	116.82	17.03	5.70	8.56
Expt. gp 2	17	109.12	12.66	111.82	11.00	2.71	9.21
Control	19	109.42	15.49	109.31	14.48	0.11	6.44
Cognitive Abilities Tasks (average)							
Expt. gp 1	17	110.41	12.84	115.17	14.80	4.76	5.83
Expt. gp 2	17	110.24	10.95	112.88	10.55	2.65	6.14
Control	19	107.68	10.35	111.11	12.12	3.42	5.47

TABLE APPENDIX 2-14: t-TESTS, EFFECT SIZES AND PERCENTILES BETWEEN EXPT.GPS. OVER CONTROL GP. ON THE DIFFERENCES BETWEEN THE PRE- AND POST-TEST SCORES ON GROUP EMBEDDED FIGURES TEST SCIENCE REASONING TASK II COGNITIVE ABILITIES TASKS.

Group	t	Mc-t		S-eff	% tile
		Group Embedded Figures Test			
Expt1	8.72	8.91	p<0.0005	0.92	82.12th
Expt2	9.76	10.14	p<0.0005	0.95	82.89th
		Science Reasoning Task II.			
Expt1	4.36	4.39	p<0.0005	0.74	77.04th
Expt2	4.43	4.19	p<0.0005	0.89	81.33th
		Cognitive Abilities Task (verbal)			
Expt1	2.10	2.12	not sig	0.01	50.04th
Expt2	-4.41	-4.49	p<0.0005	0.01	50.04th
		Cognitive Abilities Task (quantitative)			
Expt1	1.01	1.00	not sig	0.11	54.38th
Expt2	-2.91	-3.07	p<0.005	<0	
		Cognitive Abilities Task (non-verbal)			
Expt1	8.84	9.01	p<0.0005	0.36	63.31th
Expt2	3.93	3.96	p<0.0005	0.19	57.53th
		Cognitive Abilities Task (average)			
Expt1	2.45	2.53	p<0.025	0.24	58.71th
Expt2	-1.37	-1.40	not sig	<0	

t = t-test
Mc-t = t-test; McNemar (1962) detailed calculations in the rest of this appendix.
s-eff = size effect
% tile = percentile

TABLE APPENDIX 2-15: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST SCORES BETWEEN EXPERIMENTAL GROUP 1 AND CONTROL GROUP ON GROUP EMBEDDED FIGURES TEST.

$$SE_{D_e} = \frac{2.481 \text{ X } \sqrt{(1-0.82)}}{\sqrt{17}} = 0.26$$

$$SE_{D_c} = \frac{2.754 \text{ X } \sqrt{(1-0.82)}}{\sqrt{19}} = 0.27$$

$$SE_{D_d} = \sqrt{0.26^2 + 0.27^2}$$

$$= 0.37$$

$$t = \frac{5.18 - 1.84}{0.37} = 8.91$$

TABLE APPENDIX 2-16: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST SCORES BETWEEN EXPERIMENTAL GROUP 2 AND CONTROL GROUP ON GROUP EMBEDDED FIGURES TEST.

$$SE_{D_e} = \frac{2.501 \text{ X } \sqrt{(1-0.82)}}{\sqrt{17}} = 0.25$$

$$SE_{D_c} = \frac{2.754 \text{ X } \sqrt{(1-0.82)}}{\sqrt{19}} = 0.27$$

$$SE_{D_d} = \sqrt{0.25^2 + 0.27^2}$$

$$= 0.37$$

$$t = \frac{5.59 - 1.84}{0.37} = 10.14$$

TABLE APPENDIX 2-17: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 1 AND CONTROL GROUP ON SCIENCE REASONING TASK II.

$$SE_{D_e} = \frac{0.951 \times \sqrt{(1-0.78)}}{\sqrt{17}} = 0.11$$

$$SE_{D_c} = \frac{0.787 \times \sqrt{(1-0.78)}}{\sqrt{19}} = 0.09$$

$$SE_{D_d} = \sqrt{0.11^2 + 0.09^2}$$

$$= 0.14$$

$$t = \frac{0.82 - 0.21}{0.14} = 4.39$$

TABLE APPENDIX 2-18: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 2 AND CONTROL GROUP ON SCIENCE REASONING TASK II.

$$SE_{D_e} = \frac{0.752 \times \sqrt{(1-0.78)}}{\sqrt{17}} = 0.09$$

$$SE_{D_c} = \frac{0.787 \times \sqrt{(1-0.78)}}{\sqrt{19}} = 0.09$$

$$SE_{D_d} = \sqrt{0.09^2 + 0.09^2}$$

$$= 0.13$$

$$t = \frac{0.76 - 0.21}{0.13} = 4.19$$

TABLE APPENDIX 2-19: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (VERBAL).

$$SE_{D_e} = \frac{10.46 \times \sqrt{(1-0.95)}}{\sqrt{17}} = 0.57$$

$$SE_{D_c} = \frac{7.303 \times \sqrt{(1-0.95)}}{\sqrt{19}} = 0.37$$

$$SE_{D_d} = \sqrt{0.57^2 + 0.37^2}$$

$$= 0.68$$

$$t = \frac{7.12 - 5.68}{0.68} = 2.12$$

TABLE APPENDIX 2-20: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (VERBAL).

$$SE_{D_e} = \frac{8.892 \times \sqrt{(1-0.95)}}{\sqrt{17}} = 0.48$$

$$SE_{D_c} = \frac{7.303 \times \sqrt{(1-0.78)}}{\sqrt{19}} = 0.37$$

$$SE_{D_d} = \sqrt{0.48^2 + 0.37^2}$$

$$= 0.61$$

$$t = \frac{2.94 - 5.68}{0.61} = -4.49$$

TABLE APPENDIX 2-21: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (QUANTITATIVE).

$$SE_{D_e} = \frac{22.49 \times \sqrt{(1-0.89)}}{\sqrt{17}} = 1.81$$

$$SE_{D_c} = \frac{13.52 \times \sqrt{(1-0.89)}}{\sqrt{19}} = 1.03$$

$$SE_{D_d} = \sqrt{1.81^2 + 1.03^2}$$

$$= 2.08$$

$$t = \frac{7.00 - 4.90}{2.08} = 1.00$$

TABLE APPENDIX 2-22: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (QUANTITATIVE).

$$SE_{D_e} = \frac{8.403 \times \sqrt{(1-0.89)}}{\sqrt{17}} = 0.68$$

$$SE_{D_c} = \frac{13.52 \times \sqrt{(1-0.89)}}{\sqrt{19}} = 1.03$$

$$SE_{D_d} = \sqrt{0.68^2 + 1.03^2}$$

$$= 1.23$$

$$t = \frac{1.12 - 4.90}{1.23} = -3.07$$

TABLE APPENDIX 2-23: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (NON_VERBAL).

$$SE_{D_e} = \frac{8.564 \times \sqrt{(1-0.94)}}{\sqrt{17}} = 0.51$$

$$SE_{D_c} = \frac{6.437 \times \sqrt{(1-0.94)}}{\sqrt{19}} = 0.36$$

$$SE_{D_d} = \sqrt{0.51^2 + .36^2}$$

$$= 0.62$$

$$t = \frac{5.71 - 0.11}{0.62} = 9.01$$

TABLE APPENDIX 2-24: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (NON_VERBAL).

$$SE_{D_e} = \frac{9.211 \times \sqrt{(1-0.94)}}{\sqrt{17}} = 0.55$$

$$SE_{D_c} = \frac{6.437 \times \sqrt{(1-0.94)}}{\sqrt{19}} = 0.36$$

$$SE_{D_d} = \sqrt{0.55^2 + 0.36^2}$$

$$= 0.66$$

$$t = \frac{2.71 - 0.11}{0.66} = 3.92$$

TABLE APPENDIX 2-25: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 1 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (AVERAGE).

$$SE_{D_e} = \frac{5.830 \times \sqrt{(1-0.92)}}{\sqrt{17}} = 0.40$$

$$SE_{D_c} = \frac{5.470 \times \sqrt{(1-0.92)}}{\sqrt{19}} = 0.35$$

$$SE_{D_d} = \sqrt{0.40^2 + 0.35^2}$$

$$= 0.53$$

$$t = \frac{4.76 - 3.42}{0.53} = 2.53$$

TABLE APPENDIX 2-26: MACNEMAR CALCULATIONS FOR t-TEST ON THE DIFFERENCE OF THE DIFFERENCES BETWEEN PRE- AND POST-TEST BETWEEN EXPERIMENTAL GROUP 2 AND CONTROL GROUP ON COGNITIVE ABILITIES TASK (AVERAGE).

$$SE_{D_e} = \frac{6.144 \times \sqrt{(1-0.92)}}{\sqrt{17}} = 0.42$$

$$SE_{D_c} = \frac{5.470 \times \sqrt{(1-0.92)}}{\sqrt{19}} = 0.35$$

$$SE_{D_d} = \sqrt{0.42^2 + 0.35^2}$$

$$= 0.55$$

$$t = \frac{2.65 - 3.42}{0.55} = -1.40$$

Appendix 3: Training materials and their development

The Experimenter developed the materials in an attempt to give pupils the opportunity to practise skills associated with the cognitive restructuring aspect of Field-independence, i.e.;

1) disembedding the simple from the complex,
2) reorganising information to produce new patterns so breaking up a visual field and recreating it,
3) looking for hidden information systematically,
4) comparison, noting differences and similarities.
5) ignoring irrelevant and confusing material,
6) ignoring basic Gestalt theory of organising visual field into a coherent whole rather than its constituent parts.

The basic ideas came from being aware of skills required and looking for examples of when they were used and developing suitable examples for use in the classroom. The materials used in the Pilot study were modified and reorganized and expanded for use in the feasibility studies. Only minor modifications were made to the materials between the first and second feasibility studies. The materials for the final study included those of the feasibility studies but also incorporated extra written materials. This was to accommodate the fact that in the last study twice as many children were being trained at the same time, and it took 3 times as long. At the end of the appendix there is an example of a pupils' work sheet used in the last study. These worksheets formed an integral part of the training programme. The computer versions of the training materials were written by the experimenter. The programs were used to find another interesting way of getting pupils to use the materials and look carefully at information and to disembed the simple from the complex. Three particular assets of the computer were exploited;

1) its visual appeal with coloured pictures,

2) its interactive ability,

3) its ability to randomly produce many examples of the same type of question.

Description and discussion of Pilot studies' training materials.

1. Random pictures (RNDPIC).

Two figures were displayed side by side. The task for the pupil was to identify whether they differed in shape, size or colour. The presentation gradually introduced a random choice: up to four shapes, three sizes and seven colours for each one of the pair of pictures presented. The written version used sixty cards and an answer sheet to record pupil's responses. The pictures were removed before asking pupils whether the 'shapes, sizes and colours of the figures differed. When the maximum degree of possible variation in the pictures had been reached the computer then reduced the time of the display from seven seconds to one second making the task more difficult. Diagram appendix 3-1 shows an example of what might have appeared on screen: here all three variables differ.

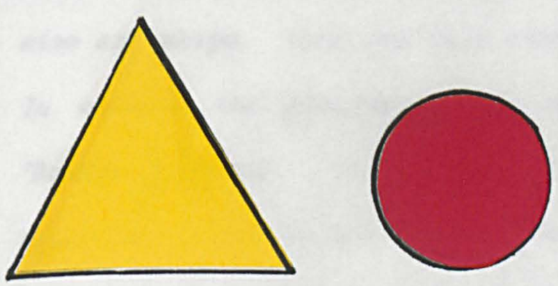


DIAGRAM APPENDIX 3-1; EXAMPLE OF 'RANDOM PICTURES' PRESENTATION.

The purpose of this program was to give elementary practise in looking carefully at two pictures, however simple, and comparing them. Any comparison requires that one element is remembered whilst looking for the same element in the another picture. This is a necessary pre-requisite to comparing information. Training with this procedure was over a relatively short period and any development of short term memory that may have happened as a consequence seemed unlikely to be permanent.

2. Matching Rows (MATCH).

Two rows of pictures were displayed one above the other, see diagram appendix 3-2 and 3-3, each component of the top row was randomly selected from six colours, four sizes and nine shapes. The second row was the same as the first except the order of the components was randomly rearranged and there was also a one in two chance of a figure appearing in the second row that was not in the first. The task for the pupil was to see if the second row did or did not have a different figure in it. If it did not they matched. If it did they didn't match. The written version had the figures presented on fifty different cards and a answer sheet to record responses. A more difficult version was also used where the colours were removed so the only variations were size and shape. This was only available in the computer version. In essence the program was a more sophisticated version of 'Random pictures'. It required much more care to make accurate comparisons. Pupils had to look for differences in orientation of a number of figures as well as their size and shape. This gave them practise at looking carefully, making accurate comparisons and re-arranging information to find out whether there was an odd shape in the second row. It was also possible to alter the *time of the display down to a minimum of 1 second. To succeed with no colours and only one second display the pupil had to analyse a lot of information very quickly. Those who could succeed at this level tended to be those who were already Field-independent. Two examples of displays are shown in diagrams appendix 3-2 and 3-3.*

DIAGRAM APPENDIX 3-2: COLOURED EXAMPLE OF 'MATCHING ROWS'

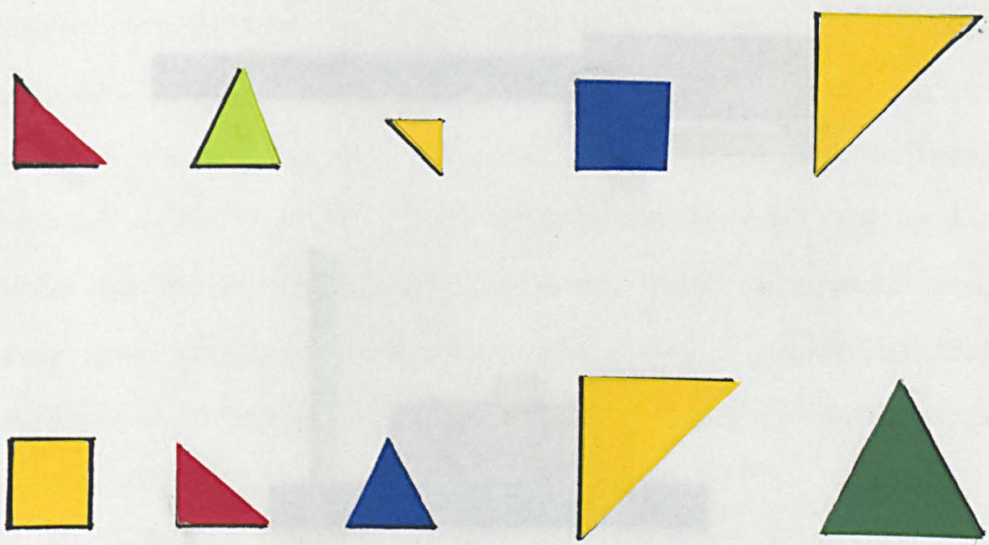
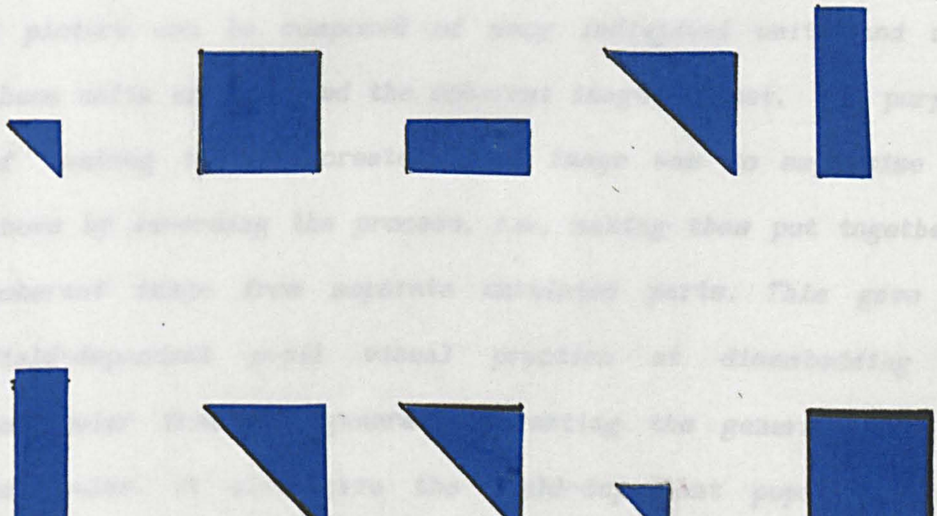


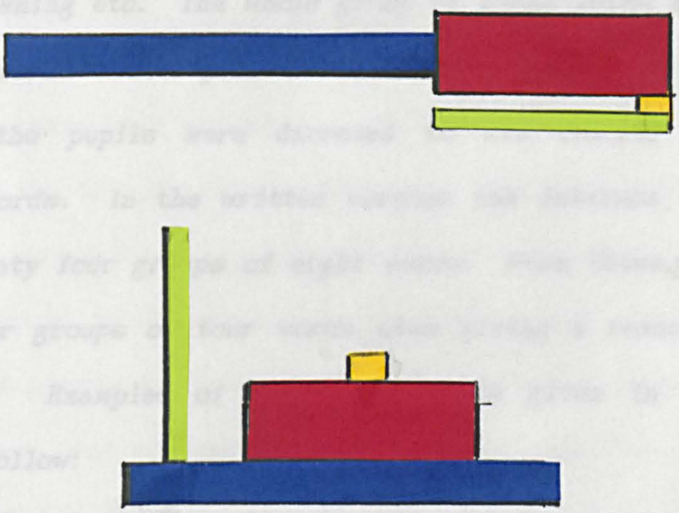
DIAGRAM APPENDIX 3-3: NON COLOURED EXAMPLE OF 'MATCHING ROWS'.



3. Rearranging.

A picture of up to six different shapes each of a different colour were given to the pupil. The pupil then rearranged the shapes to form a new picture by moving the shapes. For example the shapes in diagram appendix 3-4 represent a pen and can be rearranged to make a boat. Sixty different pictures were created.

DIAGRAM APPENDIX 3-4: EXAMPLE OF 'REARRANGING' PICTURES.



The rationale behind this exercise was to help pupils 'see' that a picture can be composed of many individual units and once these units are isolated the coherent image is lost. The purpose of asking them to create a new image was to emphasise the above by reversing the process, i.e., making them put together a coherent image from separate unrelated parts. This gave the Field-dependent pupil visual practice at disembedding the particular from the general: recreating the general from the particular. It also gave the Field-dependent pupils concrete examples of the mental processes involved in the Field-independent skills of isolating individual items from a distracting visual field.

4. Eight words.

In the computer version, written by the experimenter, eight words were presented randomly from a database of 130 words. The pupil's task was to group four of those eight words together using a rule, e.g., number of letters, starting with the same letter, meaning etc. The whole group of eight words and the four selected words were printed as a record. At the end of the program the pupils were directed to the teacher with their printed words. In the written version the database was used to print twenty four groups of eight words. From these,pupils wrote down their groups of four words also giving a reason for their selection. Examples of groups of words given in the written example follow:

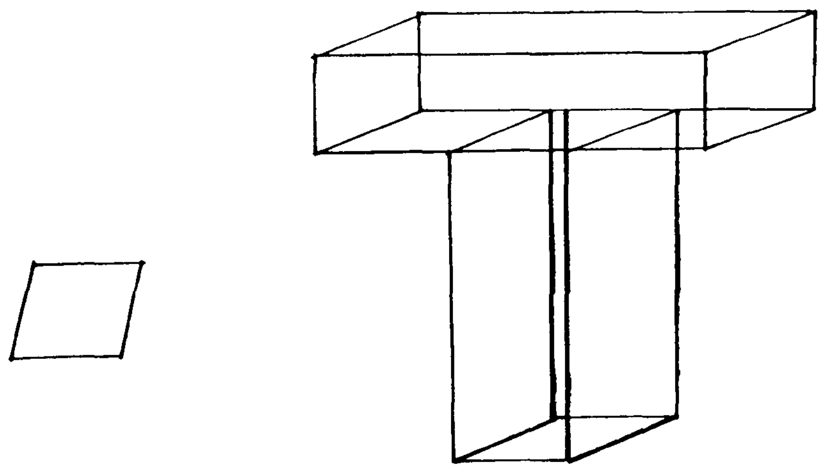
Shadow	Doctor	Mug
Orange	School	Jelly
Jumbo	Orange	Photograph
Owl	Juice	Lighthouse
Hamburger	Balloon	Igloo
Ink	Mountain	Cheese
Dentist	Autumn	Magnet
Magnet	Lighthouse	Envelope

For example the middle group of words could have had the four six letter words put together, i.e., doctor, school, orange, Autumn. The third group could have had containers i.e. mug, lighthouse, igloo and envelope. The purpose behind this exercise was to get the pupils to look carefully and to reorganise the information presented by putting it into categories of their own. The reasons for the choice did not really matter as long as the pupils had looked carefully and had gone through the process of organising and reorganising the information.

5. Embedded figures.

Two figures were presented: a simple figure and a more complex figure. The task was to find the simple figure embedded in the more complex one. In the computer version, written by the experimenter, the simple figure had to be superimposed over part of the complex one so that it could not be seen as a separate figure. In the written version the problems were given as diagrams on paper and the pupils were required to draw the simple figure on the complex one. The purpose of this task was to give a simple introduction to the problem of disembedding the simple from the complex. There were 80 figures of increasing difficulty see examples in diagram appendix 3-5, and the whole exercise took no longer than 30 mins in the whole training period. The patterns were similar in their concept to those of the practise items of the Group Embedded Figures Test. Because of criticism that this training could be construed as training for the test items themselves other tasks were substituted in the final study.

DIAGRAM APPENDIX 3-5: EXAMPLE OF 'EMBEDDED FIGURES'



Complex example

Description and discussion of 1st Feasibility studies' materials.

6. *Shape in shape (SHP/SHP):*

This was a program written by the experimenter in which the computer presented pictures made up of outline shapes of squares, rectangles or triangles. The pupil was asked how many of a particular shape there were in the picture, e.g., squares, rectangles or triangles. The computer told them if they were correct or not. If the pupil was correct the shapes were coloured in quickly, if not they were coloured in more slowly. Many of the pictures, about sixty in all, were complex with many shapes overlaying and embedded in each other. There are 14 squares in diagram appendix 3-6 and 13 triangles in diagram appendix 3-7.

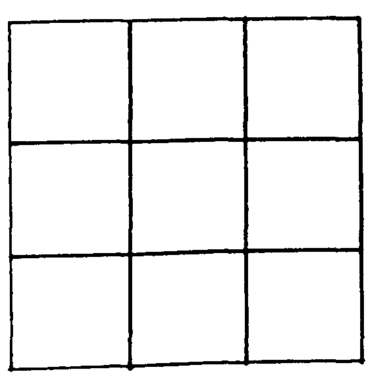


DIAGRAM APPENDIX 3-6 EMBEDDED SQUARES 'SHAPE IN SHAPE'

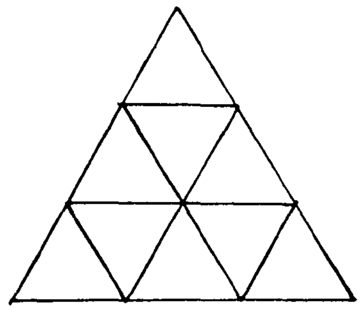


DIAGRAM APPENDIX 3-7 EMBEDDED TRIANGLES 'SHAPE IN SHAPE'

In the written version the figures were presented on cards with an answer sheet to fill in. The feedback was from the teacher explaining the answers or directing the pupils to the computer as the computer and written versions were the same. Many pupils thought that these were going to be very easy but found the more complex ones very difficult. The experimenter did have this prepared as written task from the pilot study of the materials and some pupils found it easier to pencil over the shapes to find their answers but found the feed back of computer showing the answers very valuable. The program gave pupils practise in being systematic and disembedding visual information, i.e., finding simpler information in a complex field of similar information. It also gave them plenty of examples of one piece of information overlapping and being part of another, e.g., a line serving a common edge to a number of shapes. The exercise gave Field-dependent pupils practise in separating overlapping information and re-arranging it to make new patterns.

7. Pattern (PATTERN).

This was a commercial program written by the Micro-electronics programme. The program presented three or five grids of 4, 9 or 16 squares each. The squares had various parts blocked out. The task was to match a fourth or sixth grid (depending on the degree of difficulty) with one of the existing three or five. The program had 3 levels of difficulty determined by the complexity of blocking of the squares. Once pupils had mastered this type of presentation a modified version prepared by the experimenter was given. Here the presentation could be removed after a preset time so the pupil did not have a constant pattern for comparison. The more able pupils became very adept. They could manage the most complex presentation displayed for no more than 1 second and get eight out of ten correct. Examples of the displays are give below in diagrams appendix 3-8 and 3-9.

DIAGRAM APPENDIX 3-8: EXAMPLE OF SIMPLE 'PATTERN' PRESENTATION

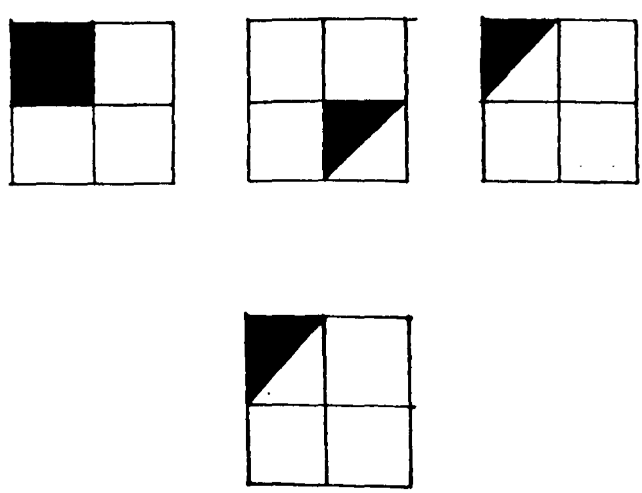
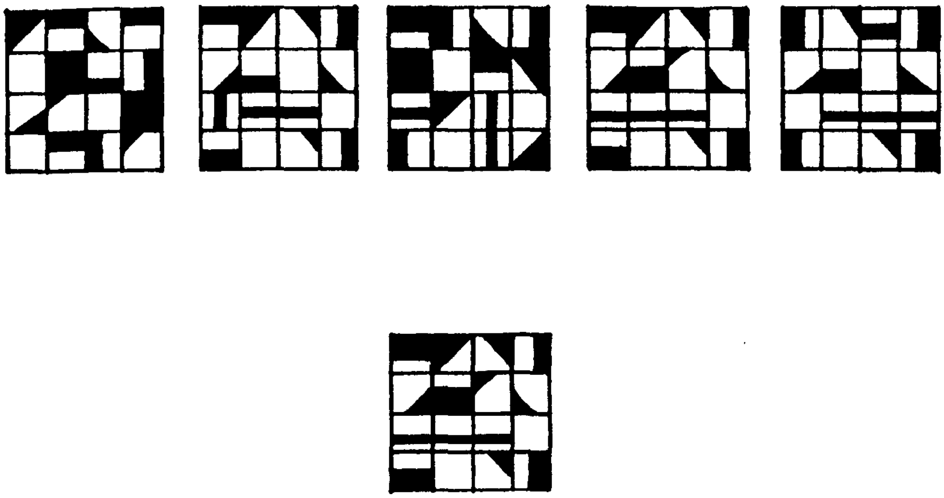


DIAGRAM APPENDIX 3-9: EXAMPLE OF COMPLEX 'PATTERN' PRESENTATION



This program gave the same type of practise as 'Matching rows' and 'Random pictures', but the patterns could be much more complex. To succeed it was necessary to disembed a recognisable pattern from the fourth or sixth grid and scan the other three or five for that pattern.

8. Word searches.

These were a 10X10 matrix of letters in which were embedded words relating to the science topic or subject matter they were studying at the time, for example the following were part of a topic on reproduction;

R	A	D	I	C	L	E	O	K	C
E	B	V	E	J	P	W	F	S	O
S	S	L	X	N	A	T	S	E	T
P	O	Q	A	V	E	R	O	E	V
O	R	E	R	R	L	O	Y	D	L
N	B	J	M	Z	U	P	R	S	E
S	C	A	R	V	M	I	B	R	D
E	L	G	H	P	U	S	M	K	O
N	Y	Z	P	G	L	M	E	G	N
M	I	C	R	O	P	Y	L	E	J

I	I	H	C	K	T	H	J	Q	M
P	F	G	N	I	T	T	O	L	B
I	N	M	N	F	M	A	I	Z	E
P	E	A	S	S	H	O	O	T	C
E	R	O	O	T	Y	I	D	N	B
T	R	Q	W	A	D	E	I	R	D
T	F	O	Z	R	H	T	N	V	U
E	R	O	R	C	X	K	E	K	S
G	J	U	I	H	W	V	V	O	O
G	T	M	B	G	V	P	N	D	D

The words hidden in these two squares are; radicle, pipette, geotropism, plumule, iodine, shoot, phototropism, soaking, embryo, starch, bean, testa, dried, growth, scar, germination, maize, cotyledon, response, blotting, peas, root, micropyle, absorb, seed.

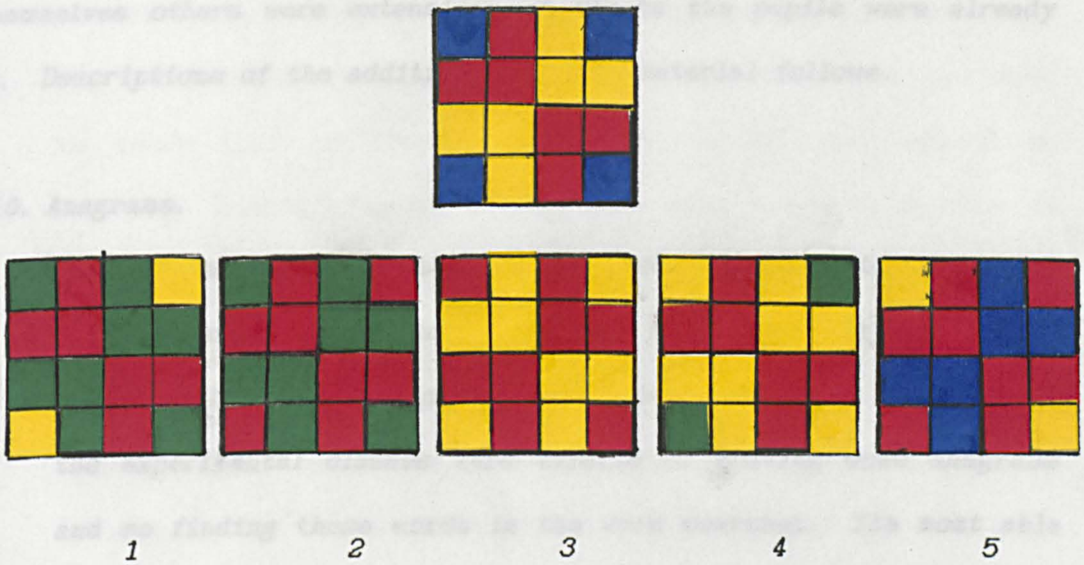
Generally pupils were not given a list of words. They were only given a list if they; 1) had tried for some time to solve the problem or 2) were of very low ability and therefore would be discouraged by having the task made too difficult. Once the topic or section of work was complete the answers were given to the pupils. The process required that a child looked for familiar patterns although the particular patterns were not always known beforehand. The pattern may be in the correct order across or down, reversed or on the diagonal. To solve this type of problem pupils had to be systematic, to discard the irrelevant, not be distracted by the superfluous letters and be able to disembed words they knew from a complex distracting whole. The exercise therefore gave Field-dependent pupils training in Field-independent skills.

In the 2nd feasibility study the following were added.

9. *'Continuo' game.*

The rationale behind this exercise was to encourage pupils to look carefully at a complex field and to isolate the particular from it in a systematic way. To obtain a 'good' score very careful analysis of the cards on the table was required. It was necessary to work out potential scores of all the cards the *player had in all of their 4 orientations. The process therefore required much disembedding and constructing of visual information. This gave the Field-dependent pupils concrete repetitious examples of the mental processes involved in isolating relevant individual items from, a distracting visual field of similar, but irrelevant information. The game was played with cards on which there were 16 squares made up of some combination of four colours. The aim of the game was to place one of the cards a player had next to one of the cards already on the table, so that not only did, e.g., two blue squares touch, but they produced the longest possible continuous run of blue squares. Scoring was achieved by recording the number of squares in each continuous run of colour that a player produced. The skill was in choosing the one card, in the player's 'hand' of five, that produced the longest run of colour against the cards already on the table. For example if the layout in diagram appendix 3-10 had been on the table, and the 5 numbered cards at the bottom had been those in a player's hand, then cards 1 and 2 would produce a score of 6 because of the run of red, cards 3 and 4 would produce a score of 12 because of the runs of red and yellow. Card 5 would produce the highest score placed so that red, blue and yellow touched giving 3 runs of colour: the red giving 6, the blue 4 and yellow 4.*

DIAGRAM APPENDIX 3-10: 'CONTINUO' EXAMPLE.



Description and discussion of the training materials in the final study.

Part of the purpose of this study was to see if training materials could be integrated into the pupils' normal work. It was also necessary to develop new materials as the study was conducted over one academic year rather than one term and four times as many pupils were being trained as in the first feasibility study. Pupils came in two blocks of two classes each and this produced logistical problems of organising staff and materials especially computer time. Appendix 4 is a report on organisation and training of the other member of staff. The computer materials remained the same with the inclusion of an 'Anagram' program (see below) but the written materials varied considerably. 'Continuo' was used as before. Word searches were used but incorporated into pupils' work sheets. 'Embedded figures' was removed because of similarity with test items in the 'Group Embedded Figures Test' and 'Re-arranging' was removed because pupils found it uninteresting. Additional written material was compiled, trialed and modified before being given to pupils taking part in the final study. Some work sheets were written complete in themselves others were extensions of sheets the pupils were already using. Descriptions of the additional written material follows.

10. Anagrams.

All the words used in the word searches for any topic were first given as anagrams. It proved to be a very useful way of keeping a mixed ability class productively occupied. Most children in the experimental classes were capable of solving some anagrams and so finding those words in the word searches. The most able pupils solved both to completion in most of the twelve topics studied. The task gave practise in two Field-independent skills: disembedding relevant clues and reorganising information. As a lot of words were used (up to 30 per topic for 12 topics). The experimenter wrote a computer program to shuffle the letters randomly. This had the added advantage of removing any influence the experimenter might put on construction of the anagrams'. Examples of the presentation can be seen in the sample work sheet given at the end of this appendix. Two versions of a computer program that presented anagrams were used. The first was a database of words that came with the program. In the second the experimenter modified the database to use words found on the work sheet for any particular topic. The program selected the words randomly and shuffled the letters randomly to produce a new problem every time within the realms of chance. The computer gave feedback on whether each letter tried was correct, and kept a score.

11. Shuffled sentences.

This was just another way of doing the same type of mental exercise as the anagrams above, i.e., disembedding relevant clues and reorganising information. All the sentences were the same as those that had been included in pupils' work sheets or reference books. Nearly all the sentences had been written in their exercise books at some time during a topic. This enabled the less able pupils to look back in their books and search for the sentences and solve the problem by matching, which also required basic Field-independent skills, i.e., careful comparison of similar but different information while ignoring irrelevant information. Some of the least able who scored, e.g., 0, 1 or 2 on the Group Embedded Figures Test found even this too difficult. Examples of shuffled sentences can be seen in the sample work at the end of this appendix.

12. Sentence gaps.

This exercise was seemingly easy but a lot of Field-dependent pupils had difficulty with it (see example below). However most pupils enjoyed the challenge of sorting out what the sentences said, and pointing out typing errors. In the first topics the experimenter wrote a computer program to produce the gaps randomly but these proved too easy for many. From these the type used below was developed where a deliberate attempt was made to make new words from the end of one word and the beginning of another.

Example of sentence gaps from topic 12.

See dsdonot germ in atew hen the yarec old, dryan d wit ho uto xy gen. Lig h tisess en tial forth egrow thof aplan tbuts eed sgerm in ate bet terin dark ness. The reares ever alp arts toas eedab road be anw hich isal arges eed show sth esep artsv eryc lear ly abeanis co vered byath ickbr own co atcall edatest a. The reisab lack regi onon thet opofabe an call edhil um. This isw here theb eanw as jo in edto itspod. Be nea ththe hil unth ereisa tin yh olec all edamic ropyle. be ant akesup w ater th rough th isis mic ro pylean dsw ells.

This type of activity gave pupils practise in ignoring irrelevant cues, i.e., words constructed from parts of other words, disembedding these constructed words and rebuilding the parts into new words until they could make some sense out of them. The more Field-independent pupils began to find these fairly easy after some practise but the Field-dependent pupils never found them easy but did get much quicker as they had more experience. This was a very easy way of giving pupils practise in the Field-independent skills of disembedding, reorganising and ignoring distracting information, and at the same time getting them to read and learn information related to the topic they were studying.

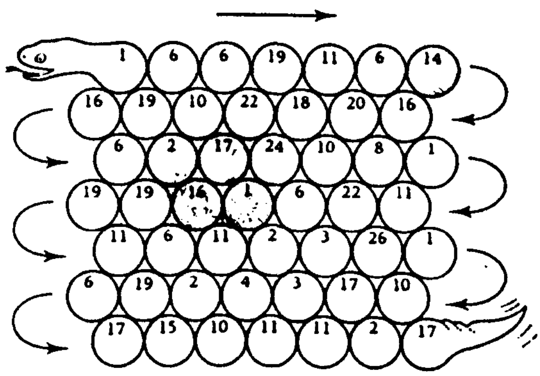
13. Word puzzles.

These were taken (with the publishers permission) from Veronica Millington (1985) book of 'Word Teasers'. An example is given in diagram appendix 3-11. All the examples used required similar mental processes to those used in 'anagrams', 'shuffled sentences', 'clueless crosswords' and 'sentence gaps'. Many of the puzzles incorporated elements of some or all of these. The puzzles therefore provided another way of giving practise in the *same sort of problem without continuous repetition of the same thing. Some of the less able pupils found some of these problems too difficult so were diverted to another activity. The puzzles were however very useful for the more able pupil who found some of the other activities easy.*

DIAGRAM APPENDIX 3-11: EXAMPLE OF A WORD PUZZLE

A Creepy Code

If DRAGON-FLY = 3.17.2.8.16.13.—5.11.26 and JUMPING SPIDER = 9.22.14.15.10.13.8.—20.15.10.3.6.17, break the code and then track the names of six more insects and creeping creatures through the segments of the snake from head to tail.



14. Random experiments

An example or two of these was included in every topic. A method list was given for an experiment either that the pupils had done or one that was an extension of what they had done. The purpose was to make them think carefully about, and to give practise in, reorganising information with which they were familiar but with the information presented in an unfamiliar way. Any Field-independent pupil needs to be able to carry out such reorganisation of information to produce recognisable logical patterns and not be confused by the other salient material. It was also a way of getting pupils to use their limited scientific skills to design an experiment for themselves. This type of activity was a link between the fairly abstract training materials and the kind of process that was finally required of pupils, i.e., being able to isolate relevant variables from a range of possibilities. A Field-dependent pupil has a great deal of difficulty in isolating what is relevant in an experiment and what can safely be ignored. An example from topic 10 is given below.

Re-order the following instructions to carry out the experiment correctly;

1. *Take the weight of the bowel* away from the *weight of the bowl and the wet food.*
2. Re-weigh again
3. Re-weigh
4. Take the *weight of the dry food* away from the *weight of the wet food* to give the weight of the water lost.
5. Take the *weight of the bowl* away from the *weight of the bowl and dry food.*
6. If the weights from 3 and 2 are the same continue otherwise re-weigh.
7. Weigh the bowl.
8. Weigh the bowl and the wet food.
9. Reheat.
10. Heat the food in a bowel at 100 °C for 24 hours.

What is the correct order ?________________________

15. Clueless crosswords.

The first stage was to substitute the letters for the numbers given at the bottom in the crossword wherever those numbers appeared: then try to solve at least one word. If pupils found the problem too difficult, one word was given as in the case below, i.e., GIMLET in the top right hand corner. Now that new combinations were known these numbers could be substituted for their correct letters in the rest of the crossword. New words could be deduced and the process repeated to completion. The rationale behind this exercise was that it required easy one to one comparison and systematic disembedding of simple, easily recognisable information from a field of similar but distracting information. It gave the Field-dependent pupils practise in addressing salient cues and not being side-tracked by other information. These attributes are necessary to become Field-independent.

17	13	2	2	1	24	24	XX	7	14	15	24	1	19
							XX	G	I	M	L	E	T
6	XX	XX	14	XX	1	XX	XX	25	XX	6	XX	XX	25
	XX	XX		XX		XX	XX		XX		XX	XX	
26	XX	XX	9	12	6	10	16	24	1	17	XX	XX	21
	XX	XX									XX	XX	
15	14	10	3	XX	7	XX	XX	16	XX	2	6	6	17
				XX		XX	XX		XX				
25	XX	XX	24	25	13	5	6	14	10	XX	15	XX	13
	XX	XX								XX		XX	
10	6	5	1	XX	1	XX	XX	10	XX	XX	25	6	3
				XX		XX	XX		XX	XX			
16	XX	14	XX	XX	XX	XX	6	7	6	19	1	XX	XX
	XX		XX	XX	XX	XX						XX	XX
XX	XX	17	25	13	2	1	XX	XX	XX	XX	21	XX	26
XX	XX						XX	XX	XX	XX		XX	
9	25	7	XX	XX	4	XX	XX	9	XX	16	6	24	14
			XX	XX		XX	XX		XX				
14	XX	14	XX	17	25	2	2	14	10	14	XX	XX	24
	XX		XX								XX	XX	
5	6	24	1	XX	17	XX	XX	9	XX	6	8	14	24
				XX		XX	XX		XX				
14	XX	XX	21	1	17	19	17	6	10	16	XX	XX	14
	XX	XX									XX	XX	
9	XX	XX	21	XX	6	XX	XX	16	XX	1	XX	XX	6
	XX	XX		XX		XX	XX		XX		XX	XX	
2	1	24	26	20	10	XX	9	6	16	15	14	13	15
						XX							

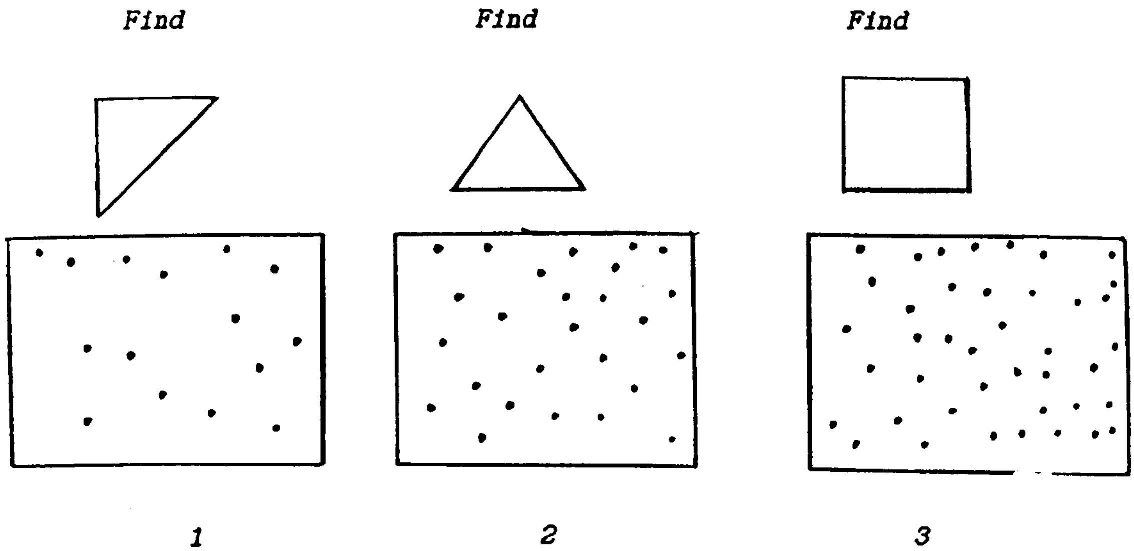
1	2	3	4	5	6	7	8	9	10	11	12	13
E												
14	15	16	17	18	19	21	20	22	23	24	25	26
	M										O	

All pupils regardless of ability enjoyed doing these. The experimenter had to keep producing more and more of them.

16. Figures in dot maze.

This activity was designed as a direct replacement for "Embedded figures' in feasibility studies one and two. A similar activity that required the same skills as 'Embedded figures' was necessary but one that could not be seen as practise for the 'Group Embedded Figures Test'. Having read Fruerstein's (1980) work and his training materials the experimenter developed one of the training strategies, i.e., looking for regular geometric shapes in a maze of dots. It needed a large number of examples so the experimenter wrote a computer program to produce them. Coordinates of geometric shapes were entered and how many distracting dots were required. The computer plotted the shape, filled the space with randomly placed distracting dots and printed the result. These were photocopied. The three shapes that were hidden in the maze of dots were a right angled triangle, a square and an equilateral triangle. Each of these had twelve examples at each one of three levels of difficulty: 1. twelve distracting dots, 2. twenty four distracting dots and 3. thirty six distracting dots. This gave therefore one hundred and eight examples. This activity was given at different times throughout the year as pupils found working on them for short periods interesting but boring if too much time was spent on them.

DIAGRAM APPENDIX 3-12: EXAMPLE OF 'FIGURES IN A DOT MAZE'.



In diagram appendix 3-12 (1) above has a hidden right angled triangle and 12 distracting dots: diagram appendix 3-12 (2) has a hidden square and 24 distracting dots: diagram appendix 3-12 (3) has an equilateral triangle hidden and 36 distracting dots. This exercise developed the classic Field-independent skill of disembedding relevant information from a distracting field of irrelevant information, i.e., find a given pattern in a maze of visually confounding data.

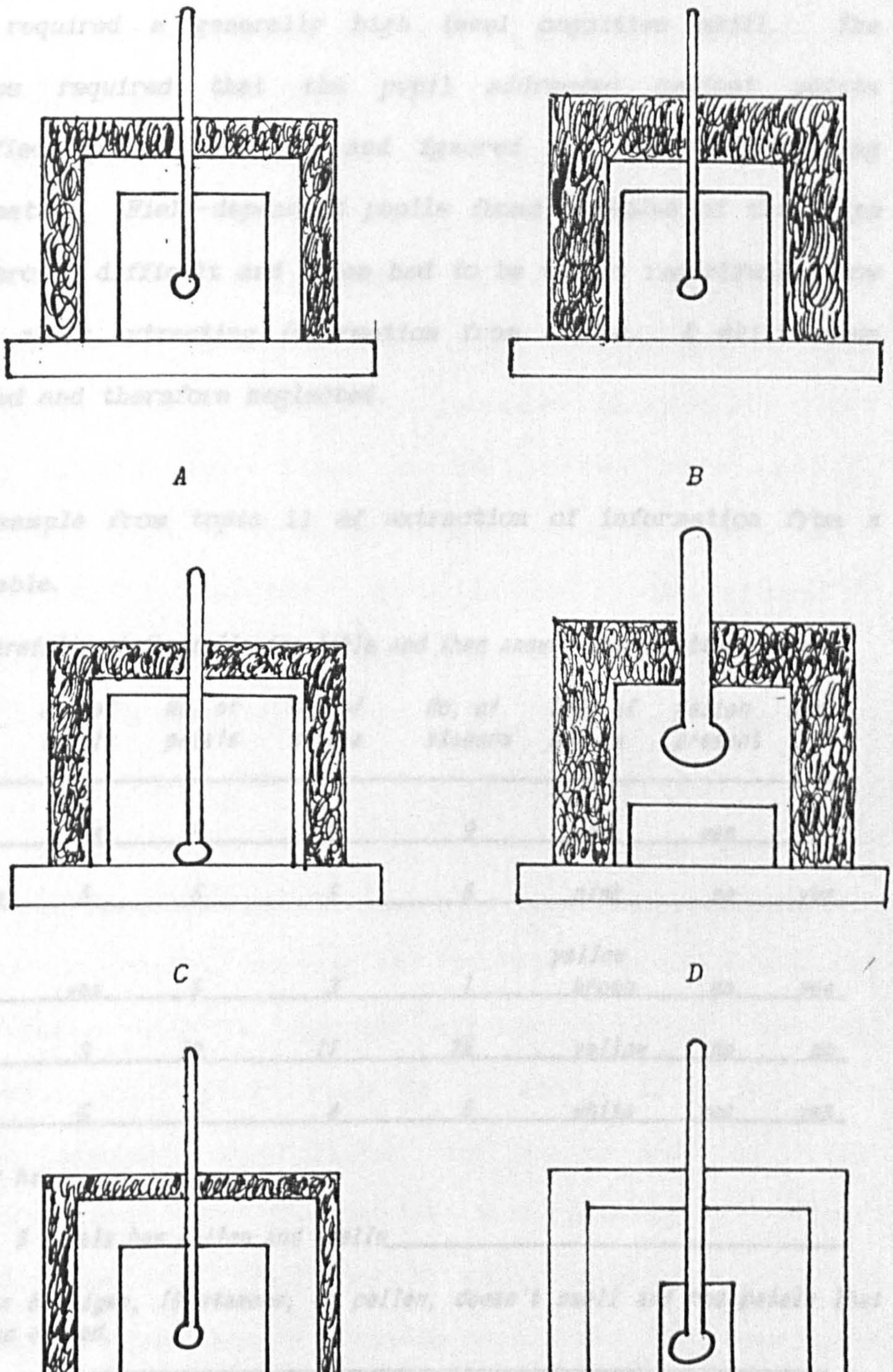
17. Spot the difference.

Pairs of pictures were used and pupils were asked to find all the differences they could see between one picture and the other. This was not cognitively very difficult but it did require concentration, careful observation, comparison and an ability not to be distracted by other parts of the picture that were not relevant to the task, i.e., to be successful it required a systematic approach.

18. Comparison of diagrams and the significance of differences.

This was a more sophisticated version of 'spot the difference'. A correct diagram labelled (A) of some science apparatus that the pupils had been using was given with up to five variations. Diagram (A) in diagram appendix 3-13 showed a container in the centre containing hot water. Around it was an air space and around that some insulation. A thermometer was placed in the water. The original experiment for the pupils was to find out how fast the water cooled with various types of insulation and sizes of water container. The variations in diagrams (B) to (F) from (A) were often small and insignificant, e.g., the difference between the thermometer shapes in A and C. The differences between thickness of insulation, size of the water container and air gap were differences that would effect the outcome of the experiment. The pupils were asked to isolate the way that diagrams (B) to (F) differed from (A). Next they were asked whether any of the differences were 'significant', i.e., would they have any effect on the outcome of the experiment and if so how? This was usually done by classroom discussion or discussion in small groups. This type of activity was a link between such activities as 'spot the difference' and classroom activity. Most of the pupils found most of the differences in such problems but Field-dependent pupils found it very difficult to 'see' whether they were relevant or not. There was always the problem of being able to select from the information that which was relevant and that which was not. This type of exercise was most valuable in giving Field-dependent pupils practise at extracting the relevant and ignoring superfluous material.

DIAGRAM APPENDIX 3-13: EXAMPLES OF COMPARISON AND SIGNIFICANCE.



19. Extracting items of narrow criteria from a table of complex information.

This required a generally high level cognitive skill. The process required that the pupil addressed salient points specified by the question and ignored the other distracting information. Field-dependent pupils found examples of this type of exercise difficult and often had to be taught individually how to go about extracting information from tables. A skill often assumed and therefore neglected.

Example from topic 11 of extraction of information from a table.

Look carefully at the following table and then answer the questions below,

Name of flower	No. of sepals	No. of petals	No. of stigma	No. of stamens	Col. of petals	Pollen present	Smell
Polygonium	yes	6	3	9	red	yes	yes
Rhododendron	5	5	5	5	pink	no	yes
Orchid	yes	6	3	1	yellow brown	no	yes
Buttercup	3	10	11	25	yellow	no	no
Lily	5	5	4	5	white	yes	yes

Which flower has;

1, 5 petals, 5 sepals has pollen and smells____________________

2, more than 8 stigma, 10 stamens, no pollen, doesn't smell and has petals that are not green or red,

____

3, petals that are red or yellow, has less than 10 stigma, less than 10 stamens and has pollen present

____

4, the same number of petals, sepals, stigma and stamens,____________________ *These training materials were often incorporated into extension work sheets. Some topics were completely re-written like the example given at the end of this appendix. Other materials were given as separate sheets, games or time with a computer. The pupils enjoyed using the materials and it was often difficult to stop them and steer them back to the conventional classwork required by the school. The only pupils who found any of the work boring were the least able. Presentation of materials such as these is certainly possible in extension work sheets. Many of the basic ideas can be included onto existing worksheets and therefore in existing schemes of work without major disruption. It would be possible to re-write most schemes of work to include training materials. The experimenter would not suggest that these materials are a definitive list. They serve as examples of ideas that work. If any school were to adopt such an approach many more examples could be found. The advantage of such a scheme as this is that it is the isolation of the idea of reorganising, sorting the particular from the general, sorting the relevant from the irrelevant and being systematic that is important not any particular exercise. Some of the more 'traditional' staff in the school often felt that working on the materials was 'playing' and had no place in 'real' science teaching and that the pupils were missing a 'proper' education. Now that the ideas can be shown to produce positive results it should be possible to persuade more staff that time spent on the development of Field-dependence is worthwhile and can lead to increased levels of scientific thinking.*

Finally there follows an example of complete topic which shows how the materials were integrated into the pupils work.

Topic 2: Plant debris and earthworms.

Where can we find plant debris ?

Information

We can find plant debris, which is made up of old leaves, bits of twigs, moss and peaty soil, under hedges and in woods. Often the debris will seem to be dead or lifeless but there are usually many kinds of small animals which live there.

Living things can be divided into 2 groups - plants and animals.

Animals can then be divided into those;

with backbones (mammals, birds, reptiles, amphibians and fish).

and those without backbones (worms, snails, arthropods etc.).

We are going to look for small animals from one of these groups ... the arthropods.

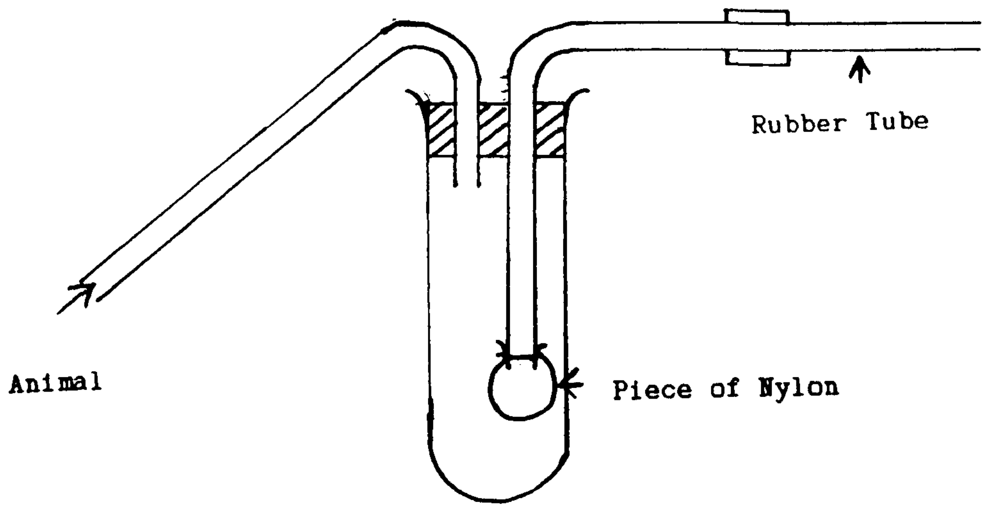
Experiment 1: Sorting animals from plant debris.

You will need:

plant debris, (e.g., damp leaf litter from a wood or under a hedge), newspaper, a 'pooter' (see page 2), a small paint brush, blunt forceps, 4 small dishes, a mounted needle, plastic bags, Activities book 1.

What to do;

1. Collect some leaf litter from under a hedge or in a wood and put it in a polythene bag.
2. In the laboratory empty your bag onto a sheet of newspaper and spread out the plant debris.
3. Gently pick up anything which moves by sucking it up in the pooter, or using forceps, or using a paint brush. Use the mounting needle to probe and spread out the debris. Try to break up the big pieces.
4. Put the animals in the dishes and look at them carefully with a hand lens. If they move too much ask your teacher how you can slow them down.



5. Fill out the table below for each type of animal that you have found. Use Activity book 1 page 41 to help identify the animals.

colour	length in mm	number of legs	has it got wings?	is body segmented?	name animal

What to write.

1. Take two animals from your list and answer the following questions.

Name of the two animals ?__________

What are their similarities ?__________

What are their differences ?__________

Which characteristics did you use to identify them ?__________

2. Take two <u>other</u> animals and answer the following questions.

   Name of the two animals ?________________________________

   What are their similarities ?________________________________

   ____

   ____

   What are their differences ?________________________________

   ____

   ____

   Which characteristics did you use to identify them ?__________

   ____

   ____

3. We can group the animals found in different ways: for example colour.

   Think of 5 other ways of grouping the animals.

   1. ____
   2. ____
   3. ____
   4. ____
   5. ____

   The best method of grouping was __________ because __________

4. Most of the animals seen belong to the group called <u>arthropods</u> because they have jointed legs and a body separated into parts.

   A worm is not an arthropod because ________________________

   ____

   A spider is not an insect because ________________________

   ____

   Why do you think plant debris is a good place to find small animals?

   ____

WHEN YOU HAVE FINISHED PUT YOUR ANIMALS BACK WHERE YOU FOUND THEM

What can we find out about earthworms ?

You will need;

Jam jar of worms, hand lens, newspaper or tray, centimetre rule, Activities book 1.

What to do;

1. Empty you worms onto a sheet of newspaper or tray.
2. Sort out your worms into their different types (see Activities book 1 page 50 figure 45).

Answer the following questions.

1. How many different types of worm do you have ?________________

2. The longest worm is _____ cm and the shortest is __________ cm

3. Find out more about the longest worm in the world. ___________

____

What to write.

Write the date and the title Earthworms in your book and copy figure 47 page 51 of Activities book 1.

Complete the sentences below;

The worm is not the same at both ends. One end called the _______

and the other is called the ______________

The worms body is divided into many ___________________

The skin feels ________________

Through the skin I can see a _________________ all along the back.

What else can you see or feel ?____________________________________

____

How sensitive are earthworms ?

You will need;

Earthworms, water and a teat pipette, lamp and supply, obstacle, sandpaper and glass.

What to do;

Test the earthworms' response to:- gentle finger touch, water drops, object placed in its way, light and dark and rough and smooth.

Record your results below:-

Stimuli	Response
Finger touch	
Water drops	
Object placed in way	
Light and dark	
Rough and smooth.	

Conclusion

the earthworm is most sensitive at ______________________

What to write

Write the date and title 'Experiment to show that earthworms are sensitive to vibrations'.

Now see if you can work out the details of such an experiment for yourself. Lay out your work as shown below using the indentations (if you don't know what this means ask your teacher).

Apparatus

Earthworms ....

Method

1.
2.
3.
.
.
.

Results

I think that the earthworm would ....

Conclusions

I think the earthworms would be sensitive to vibrations because ....

Rearrange the following sentences correctly.

1. things be into plants animals divided and groups two can living.

2. backbones those without are with into and those backbones divided animals then

3. Most into the group seen because a animals arthropods called and they to separate of the have belong parts body jointed legs.

4. an because jointed has got is arthropod worm legs it not not a.

5. has body parts its has four to because two legs insect not pairs spider and an is of it a.

6. the ends not at is same both worm the.

7. other and is anterior on the posterior end is.

8. many into the body divided worms segments is.

9. feels skin slimy the.

10 back blood vessel through skin the I the can along see all a.

____

____

____

Sort out gaps in the following so that it makes easier reading.

Li vi ng th ing scan bed ivi ded i nt otwog roupsA nima leare the ndivi dedin toth osew ith back bonesand tho sewith outback bones mos tof the ani malsese narea rth ropod saworm i snota narth ropodb ecauseit do esnot ha vejoint edlegs andtwop artsto it sbodyt he wormis notthes ameat bothe ndsone endisc all ed theant eriora ndthe o thert hepost eriorthe wor m'sbod y isdiv idedin to m any seg ments thesk inf eelsw etands limyth rough thesk inIcan seeal inealla longthe back.

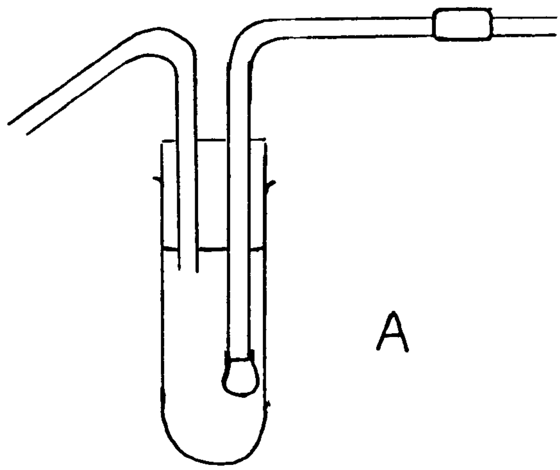
Solve the following anagrams

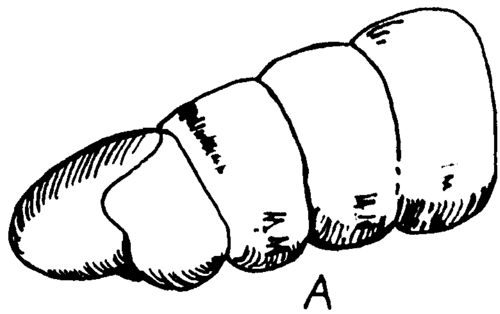
LPATN	PAAIIHBM	SGSMEETN
SREBID	IHFS	LMSYI
LSVEEA	OCNEABSKB	L OSVEESLODB
GSIWT	OSMWR	LEDASD
EATPY	SIASLN	RSALDO
HGEESD	POAHSROTRD	VELTANR
ALIMSNA	RPEOOT	RLTBSESI
LNGVII	SOCPEFR	IEVNSISET
MAASMLM	HETRAORSVN	DBSIR
EORANIRT	PERETILS	PSRETIROO

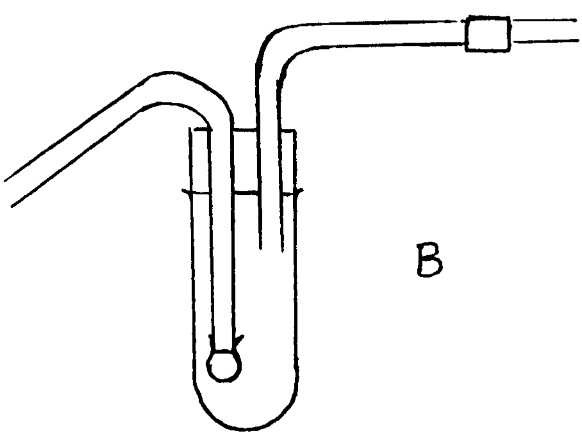
Solve the following word searches

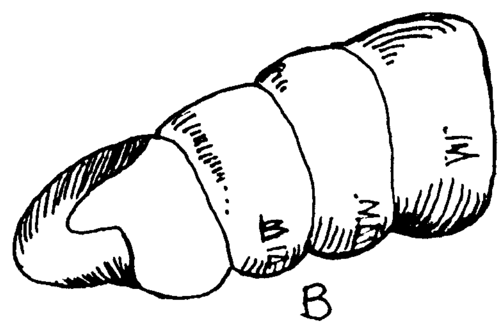
```
S D O P O R H T R A     I Z W B S E G D E H
E E L I A N S L C U     B J O X O S P S P O
G N N L H P E A C D     Z H O P O E L P W E
M H H S I F L R F O     A I D S E V A U S N
E W H D I M T T L R     N J S Q W A N O I O
N O E S I T S N I S     I O U Y F E T R R B
T R H W N F I E T A     M A M M A L S G B K
S M W I N G R V T L     A M P H I B I A E C
R E T O O P B M E Y     L J D E D I V I D A
A N T E R I O R R R     S E L I T P E R H B
```

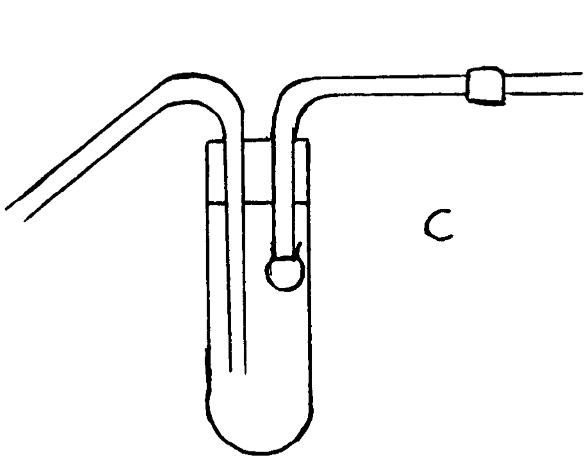
Look at the two sets of three diagrams below. Diagram (A) is correct in each case. List how diagrams (B) and (C) differ from the relevant (A). Then explain for each of the differences you have listed whether the difference would be important.

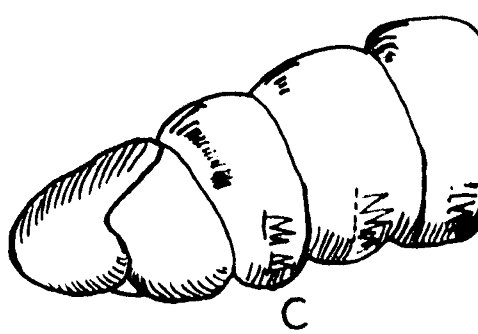












Appendix 4: Staff training.

Part 1 are the written instructions given to the other member of staff with the topics. Part 2 are the transcripts of the experimenter's interaction with the pupils developing a metacognitive language. Part 3 is the summary given to the pupils for revision before post testing.

Part 1.

The first section of this gives the instructions given to the other memnber of staff on each of the topics. The first three topics were supported by detailed discussion with the probationary teacher before each lesson. Once the pattern had been established the written instructions detailed below were given at the beginning of each topic.

Topic 4: The effect of heat on metals liquids and gases

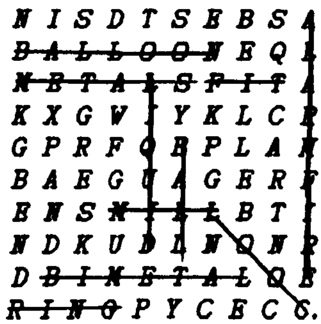
I'm sorry the quality of the copy isn't good. It was the 1st attempt at using stencils. Obviously you can only use the supplementary material after having done the appropriate work before-hand

The differences on page 2 are the large differences no the subtle ones. The emphasis is on the significance of the differences.

The pin breaking experiment can be done of course but if possible only after they have just looked at and tried to answer the questions on the top of page 3, sorry about the order. You have a duplicate of page 3 because of the quality.

Answers to anagrams and wordsearches:

metals, wire, ring, gas, liquid, bend, alarm, fire, ball, battery, Bunsen, terminal, thermometer, cool, heat, flask, metals, bell, asbestos, expand, flask, ring, bend, gauge, contract, bimetal, balloon;



Topic 5: How heat is carried.

This supplementary material generally extends the work sheets and emphasises reorganising information and representing it in different forms, and the significance of that reorganisation.

The redrawing of graphs at the bottom of page 2, I feel developes two important points, i.e.; practice at drawing graphs correctly with the axis correct and the benefit of putting 2 pieces of information on the same graph for comparison.

The questions at the top of page 3 refering to diagrams A-H are designed to develop matching and to see; the significance if any, of the errors of those that don't work and to show that it is the principle that is important not the way the apparatus is assembled.

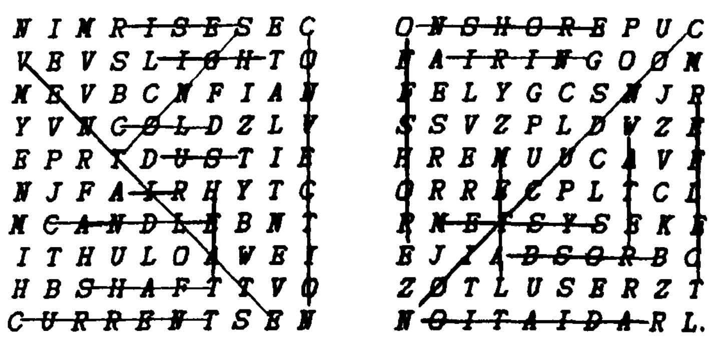
The questions referring to diagrams I-N are again just to emphasise differences and their significance if any.

Diagrams O-R require only an A B C or D answer. This could be done by class discussion. The idea again is to identify differences and if any their significance.

Diagrams P-U are to be attempted in the same way as O-R.

Answers to anagrams and wordsearches:

ventilate, box, candle, tongs, matches, heat, rises, cold, convection, current, chimney, draught, vent, ventilation, shafts, air, light, dust, onshore, offshore, water, system airing, conduction, metal, plastic, particle, metals, radiation, cadmium, silver, reflect, absorb, polished, apparatus, method, result;



Topic 6: separating substances.

The extension material for topic 6 follows a familiar pattern.

page 1: reordering of sentences; the table requires reordering of information already in their books; the 2nd table needs a list of all the colours found by children above the top line of the table, the original colours of the pens could be entered left of pen 1 pen 2 etc. the task is then to fill in the grid, pen against colours found and entering m or w depending whether colours were found by chromatography with meths. or water. If you don't get good results to extend experiment 5 use the following results;

pen colour	colours in water	colours found in meths
green	green, yellow	yellow
red	orange	blue and red
purple	orange	blue and red
brown	orange and yellow	green and red

page 2: Q's 1-4 emphasise not only whether two diagrams are different, an important observational skill but whether those differences are significant, these questions will need pupil/teacher discussion either in groups or class. Q's 5-7 are designed to help pupils organise the same information and the idea of groups within groups. Finding a suitable order for a list of instructions aids reorganisation of information and I hope tells something about experimental design and logical orders.

The remainder of the sheet I feel is self explanatory

Answers to anagrams and wordsearches:

salt, pepper, charge, electrical, iron, filings, sulphur, separate, magnetic, ink, coloured, filter, funnel, watch, glass, evaporate, distil, condenser, cooling, cobalt, chloride, boiled, dropper, pipette, beaker, solvent;

```
S O L V E N T C B C      L F I L I N G S V N
R E S N E D N O C H      I A R U H P L U S L
E G D E L I O B O L      R E C O L O U R E D
P I P E T T E A O O      E U H I N K H N H W
P G H P U S I L L R      T N A R R R Y D H A
O Q V C U S Z T I I      L N R O E T L A S T
R H Q B E A K E R D      I E G N P W C J G C
D I S T I L L A T E      F L E B P N C E P H
X Y J E H G Q V X T      M A G N E T I C L G
V E T A R O P A V E      C W S E P A R A T E.
```

Topic 7: Using coloured substances from plants

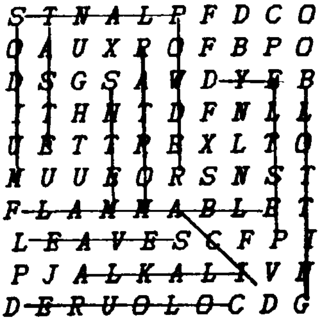
This topic is complete in itself and the extension material is in the sheets themselves or referred to on pages 5-7.

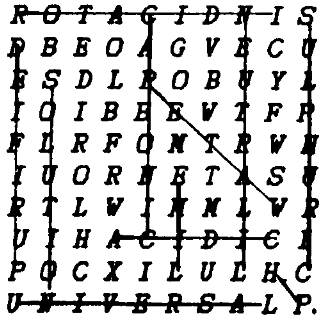
Pupils are often asked within the sheets to regroup information. This is designed to help pupils' thinking about regrouping information to find significance in the new groups that was not immediately apparent.

Page 8 contains gaps, anagrams and word searches.

Answers to anagrams and wordsearches:

leaves, mortar, meths, flammable, chlorophyll pestle, dye, blotting, coloured, plants, powder, acid, alkali, taste, sodium, solution, indicator, neutral, extract, carbonic, sulphuric, chloride, lime, universal, purified, acidic, water, vegetable, berries, roots;





Topic 8: Grouping and classification

This topic is very close to the ideas that I want. The extension material is only a single sheet. The chart on page 1 does need some explanation for pupils. Filling out the animal column is fairly straight forward; it is simply a means of identification using the animals on the work sheet. The last column requires the pupil to record how many (starting with column 1) of the 1st 5 columns they need to be able to identify the animal. They do not all need all 5 columns; e.g. the 4th animal needs only the 1st 2 columns to identify duck.

The gaps in sentences are to emphasise reorganising into recognisable patterns that make sense. The 'difference between' diagrams need careful observation and comparison in a systematic way. <u>NB there are only 10 differences in the Chinese letters</u>.

Answers to anagrams and wordsearches:

classify, animal, grouping, identify, regroup, glassware, key, coin, branching;

```
C Z B B N C F L C O
B J Y F I S S A L C
Z E G R O N B N C O
K I G R O U P I N G
P U O R G E R N C T
C E R A W S S A L G
O S H L O P C D C O
I D E N T I F Y S J
N J O Q H F D F V F
B R A N C H I N G S.
```

Topic 9: Environment.

All the following worksheets are just extensions of the ILEA worksheets. The sentences with gaps in have been deliberately shuffled to be difficult rather than just random gaps as before.

Answers to anagrams and wordsearches:

Animal, shelters, colony, tube, nest, burrow, beehive, stone, age, man, medicine, sport, clothing, chemicals;

```
C L T E V I H E E B     T C N I T X E R G B
O H S T O N E I B U     X D I N M O R T A R
L K E O S P O R T R     N J Y S P E C I E S
O P N M Q O Y I Z R     G T C U D O R P P X
N O I A I O G U Y O     N O U L D W Z K B E
Y M J N V C W N C W     E N D A N G E R E D
S L A M I N A F M T     H X E T V E F A S E
E G N I H T O L C N     C A V I T Y B L K X
G S R E T L E H S L     L X C O N C R E T E
A P E N I C I D E M     W J I N X D N R A W.
```

The shuffled sentences are those on the ILEA work sheets and are usually in the same order as they appear on those worksheets.

The clueless crosswords are of the same type as we have used before. They bear no direct relationship to the words within the topic. If the pupils need more help then the first word in the top right hand corner of the 1st crossword is GIMLET and the first word in the top left hand corner of the second is TROJEN.

The question at the bottom of page 3 refers to the diagrams on pages 5 and 6. As there are sets of diagrams each labelled A-F the exercise needs to be done three times, once for each set of diagrams.

Topic 10: Environment 2

The layout to this topic is the same as the above.

The solutions to the anagrams and wordsearches are: purified, bacteria, chemicals, disease, sterile, chlorinated, incubated, wilt, solar, still, water, salt, cools, shiny desiccator, pollution, turbid, submerged, gills, operculum, killed, cleaning, alum, leaves, supply lamp, pipe, basin;

N	I	M	E	L	I	R	E	T	S
I	N	C	U	B	A	T	E	D	T
B	U	V	S	H	I	N	Y	M	I
A	V	G	W	D	W	W	Z	Y	L
C	H	E	M	I	C	A	L	S	L
T	J	E	L	S	E	T	Y	O	K
E	Y	T	O	E	O	E	B	L	P
R	T	L	O	H	O	R	W	A	V
I	B	A	C	S	R	X	Y	R	X
A	F	S	Z	E	Y	C	E	S	P

C	D	D	O	D	V	K	P	U	R
O	P	E	R	C	U	L	U	M	D
Z	C	L	E	A	N	I	N	G	E
M	U	L	A	P	D	O	Q	Z	G
E	P	I	P	G	I	L	L	S	R
D	R	K	B	S	B	E	A	C	E
B	A	S	I	N	R	A	M	K	M
P	J	B	N	G	U	F	P	E	B
P	O	L	L	U	T	I	O	N	U
E	J	Q	D	Y	L	P	P	U	S.

The question above the 'gaps' on page 4 requires the animals on page 11 side 1 of the ILEA worksheets being grouped into two separate groups. Then each of these groups are to be subdivided into two groups each making four in all. All that is required is the four groups and the rules they used to form those groups. There is no correct answer it is the process of grouping and sub grouping that is important.

The diagrams and graphs labelled A-F on pages 5 and 6 are to be treated in the same way as topic 9. I do feel that pupils need practise in identifying relevant variables within a problem and this is a simple way of getting them to do so without a lot of equipment.

Topic 11: Growth and Development.

As there were such a large number of anagrams I felt it might be better to give the pupils a list at the beginning. The solutions and wordsearches are:

cheek, cells, methylene, blue, stain, microscope, slide, onion, skin, magnify, nucleus, gametes, egg, sperm, mobile, inherited, fertilise, zygote, internal, external, nuclei, fuse, embryo, hatch, flowers, petal, pollen, sepal, stigma, stamen, ovary, ovule, anther, growth, vacuole, sap, self, cross;

Q	S	E	S	U	F	Z	J	I	D
J	B	I	N	T	E	R	N	A	L
U	N	E	M	B	R	Y	O	W	M
C	H	H	H	C	T	A	H	F	O
I	N	H	E	R	I	T	E	D	B
C	G	F	E	I	L	C	U	N	I
L	A	P	E	S	I	L	F	D	L
P	E	T	A	L	S	R	B	X	E
Z	Y	G	O	T	E	U	M	Y	Y
J	S	L	A	N	R	E	T	X	E

C	H	E	E	K	L	F	L	C	O
G	A	M	E	T	E	B	L	U	E
N	U	C	L	E	U	S	S	D	N
N	I	H	Y	M	G	F	P	C	E
I	J	T	Q	F	S	G	E	E	L
A	U	N	Y	E	I	S	R	L	Y
T	S	O	L	D	P	N	M	L	H
S	K	I	N	I	O	G	G	S	T
P	J	N	Q	L	F	D	F	A	E
E	P	O	C	S	O	R	C	I	M

S	Z	R	S	R	E	W	O	L	F
T	T	V	A	T	R	V	V	E	L
A	D	I	P	O	U	V	A	R	E
M	H	L	G	L	B	C	R	H	S
E	V	T	E	M	R	U	D	H	R
N	U	C	W	J	A	O	O	F	K
P	I	C	Y	O	W	L	J	G	Y
A	N	T	H	E	R	E	D	P	U
P	S	S	O	R	C	G	B	N	G
P	O	L	L	E	N	Z	E	H	J.

There are a lot of reshuffled sentences you perhaps wont want to use them all. The comparison of the diagrams on page 6, and questioned at the top of page 5, has the same purpose as before, i.e., looking for and naming significant variables within the context of the subject matter.

The last exercise on page 5 I feel is something which we don't give enough practise in, i.e., extracting information from diagrams, charts and tables of information. Some of the less able will find this difficult and will need help.

Topic 12: Growth and Development Seeds.

!!!! To be able to answer the first question on my sheet, question 3 on page 9 of the ILEA sheets needs to be set up early in the topic.

The solutions to the anagrams and wordsearches are:

testa, cotyledon, micropyle, radicle, plumule, absorb, germination, geotropism, phototropism, response, scar, bean, seed, embryo, shoot, root, peas, soaking, starch, pipette, iodine, maize, blotting, dried, growth, radicle, pipette, geotropism, plumule, iodine, shoot, phototropism soaking, embryo, starch, bean, testa, dried, growth, scar, germination, maize, cotyledon, responded, blotting peas, root, micropyle, absorb, seed;

R	A	D	I	C	L	E	O	K	C
E	B	V	E	J	P	W	F	S	O
S	S	L	X	N	A	T	S	E	T
P	O	Q	A	V	E	R	O	E	Y
O	R	E	R	R	L	O	Y	D	L
N	B	J	N	Z	U	P	R	S	E
S	C	A	R	V	M	I	B	R	D
E	L	G	H	P	U	S	M	K	O
N	Y	Z	P	G	L	M	E	G	N
M	I	C	R	O	P	Y	L	E	J

I	I	H	C	K	T	H	J	Q	M
P	F	G	N	I	T	T	O	L	B
I	N	M	N	F	M	A	I	Z	E
P	E	A	S	S	H	O	O	T	C
E	R	O	O	T	Y	I	D	M	B
T	R	Q	W	A	D	E	I	R	D
T	F	O	Z	R	H	T	N	V	U
E	R	O	R	C	X	K	E	K	S
G	J	U	I	H	W	V	V	O	O
G	T	M	B	G	V	P	M	D	D.

The rest of the topic is fairly straight forward and doesn't need any explanation.

Thats all folks.

I hope that you haven't found the use of these materials too tedious. I have found faults and difficulties myself but generally the pupils have enjoyed using them and at times I've had difficulty in stopping them. It has given me materials to keep pupils productively occupied whilst talking to other groups. It has obviously taken me a lot of time and effort over some 18 months just to prepare these work sheets. I have felt it worthwhile and I hope I can show that they have some real benefit in developing pupils' observation, discrimination and scientific thinking. I realise the approach is less traditional and is open to 'it isn't real science' but it depends on what is real science, thinking scientifically or remembering experiments. Of course I am not suggesting that any other way of teaching doesn't develop scientific thinking but without the observational skills and the ability to discriminate relevant variables from a complex field of information, much of which is often irrelevant, it is unlikely that many pupils will develop the ability to think scientifically.

Thank you for your help and perseverance. I hope I have given you sufficient information without swamping you with sheets of useless data. It is a difficult line to follow between being supportive and instructional. If you have comments, criticisms or suggestions they would be most welcome.

Thank you again for your help.

Part 2

Examples of discussions with pupils implementing this approach.

(NB's Comments in brackets are those of the pupil's. All the examples listed are a distillation of many written and or verbal responses given by pupils and edited for clarity). The activities were organized into three different groups; those emphasising, 1) comparison, 2) reorganizing and 3) disembedding.

Group 1: Comparison.

Wednesday April 16th 1986.

We had a rather messy term last term so I want to go back to something we were trying to do then. If you remember we tried to look at some of the activities I had been giving you and to try and work out how you thought whilst you tried to solve them. I wrote words you suggested on the board and tried to get you to think of other words that described what went through your mind as you tried to solve the activities. I want to do a similar process nearly every lesson from now until the end of term. What I have done is to group all the activities you have done into three separate groups. I am not, as before, going to look at one particular activity but the whole group of activities and try to help you find out how you thought whilst you were trying to solve them. We will start with group one. I've included in this group the first computer program you did. If you remember this put two diagrams on the screen and it asked you whether the colours were different or the shape was different or whether the size was different. I also included the second computer program which was called 'matching' which put two rows of figures on the screen and asked you whether they matched. They did if there was no changed figure in the bottom row. The third activity I included was the 'pattern' program which gave you five figures and a sixth you had to find in the other five. I also included the clueless crosswords which required that you substituted letters for numbers and numbers for letters until solved. I will make some more of those if you like. (Yes please from pupils). More recently spot the difference pictures and the experimental diagrams that gave you diagram A as correct and you had to see if you could see how B,C,D etc. differed and whether these differences mattered. I want you now to listen carefully. Including those of you who have started working out this topic's anagrams and word searches whilst I have been talking! Think now about all those programs? the random picture, matching rows, spot the difference etc.. Can you think of a common thinking process that links all of those problems? What was the first thing you thought of doing? what do you look at? what sort of ideas come to mind? (Long pause). You can take just one of the activities and think about that if you prefer. Lets just think about the matching rows for a minute. I think they have all something very similar in common. Some of you are not concentrating. Whereas I am delighted that you want to solve the anagrams and word searches I want you to listen to what I am saying now! Lets take just the matching rows for a minute. You know what you are doing what are the words that come to mind to describe how you think about the problem. (You look at them and try to take in what sort of shapes they are). (Study). All right I quite like that as a word. (Compare). Right that's good. You compare. What do you do when you compare ? (You look for things that are similar and things that are not the same). Fine you look for similarities and differences.

What sort of word could you come up with that describes looking carefully, making comparison, looking for differences and similarities, all those things. Can you think of one word that includes all those things. (Observe them). Not quite what I'm after. Its really just another word for looking carefully. (Examine). Yes that does suggest looking carefully. Can you think of anything else. I'm thinking of a word beginning with 'a' that describes all these things. (Analyse). Well done !! That says a great deal more than just looking carefully or comparing. If you are analysing you are looking ....? (System). Use the word you have done, but the grammer is wrong. Your nearly there. (Systematically). Good you had the word. Right if you analyse something you look at it systematically. I want you now to think of times when you look at things systematically. For example it you had a medicine bottle you would look carefully at the label. Reason? (Make sure you had the right medicine). Good! what else? (How much to take). Right you look to see the dose, how much to take. Now that's one example. Now try to think of one or two others. What is it you look carefully at, and what it is you look carefully for. Just jot them down in rough. Write some of them down whilst I come around and talk to you in groups. Think about the words on the board. [The words on the board were; look, shapes, study, careful, compare, similarities, differences, observe, examine, analyse, looking systematically, characters].

Examples given by pupils;

1) *Tinned food, looking at labels for contents, e.g., additives, sugar, eat by date etc.,*

2) Look at recipes to see what is required for a meal: you might then compare to see if you have what was required by the recipe in the cupboard,

3) Soap to see if it contains things to which someone might be allergic,

4) Instructions on things bought, e.g., seeds, models, dress patterns,

5) Dictionaries and indexes to find references to information required, telephone book for telephone numbers,

6) Computer programs to find sources of errors,

7) Looking through work and answers to see if there are any mistakes,

8) Looking for traffic before crossing the road.

Friday the 18th April.

Now I want to take it just a little further than last lesson. You have a list of examples of where you look systematically at things that we got together last lesson. When you are analysing things you look at them very systematically. Lets just look for a moment at the random pictures. You had something along the lines of a rectangle and a square and you were asked whether the colour, shape or size differed. Can any of you think of a general word for the three differing things, i.e., colour shape and size. (Characters). OK I'll put it down. I'm not sure that's quite right. (Similarities). Yes but when you are looking for similarities or differences you are looking to see if the colour is the same or different, or whether the shape is the same or different, or whether the size is the same or different. Now what do you call it as a group name shape, size or colour. Now what do you call those three things together. What could be a group name for those three. Those three things are the things that are likely to, what? (Change). Who said that ! Good ! Now try to think of other words that mean change. (Three things that are different). (Alter). Good word, fine. The three things that are likely to change, the three things that are likely to alter, the three things that are likely to ....? (Transform). Too much television my children are into transformers too. Change, alter transform. There is one word beginning with 'v'. (Vary). Well done ! Now what you are looking at is the three things that may vary. Each one of those is called a variable. So you are looking at three variables.

Today I want you to write down the two words compare and variables and try to write down as many situations where you at home compare things and what variables you are comparing. I will give you an example and then I want you to think about the problems and find a few examples of your own. If you go to buy a tin of baked beans you look carefully at variables such as price, size, make etc. Now try to think of examples that are not always to do with buying things.

Pupil's examples given in class discussion:

1) Comparing humans with other animal; number of legs, eyes, hair, teeth, diet, size etc.,
2) Walking or getting a lift home; length of time, laziness, cost, ease, weather,
3) Crisps; cost, flavour, type, weight, make, influence of TV,
4) Moods; good days dad comes in smiling, chatty, doesn't slam doors, bad day dad is grumpy, sour faced, rude and bangs doors,

5) Drinks; flavour, cost, size, colour, alcoholic, type of container, additives,

6) Televisions; colour/black and white, size, cost, rent/buy, remote control, ear phone plug, computer input,

7) Sweets; type, colour, size, cost, flavour, what your friends like, what you like,

8) People; height, weight, sex, colour, religion, age, status, personality, hair colour, type of clothes worn.

Wednesday 23rd April

When you look at things systematically you look for the important variables those that are significant many are not. Lets look at the clueless crossword for example. The downward lines are drawn with exclamation marks. They are of no great importance in solving the crossword. Neither is it very important whether the blank squares are blanked out with four X's or six X's. Both these are variables in the crossword but neither are very significant in solving it. Looking for my number in a telephone directory you look for variables. The most important ones are in the order C O L L I N G S. There are other variables in the 'phone book. All the other names beginning with other letters. Once you have the C's you ignore all other names or variables beginning with C except those that begin CO. You continue like this until you have my whole name initials and then use my address if necessary. So the significant variables would be name, initials, address. Now some examples of your own. Where do you analyse systematically and what are the significant variables?

Examples from the homework were;

1) Anagrams; significant variables are groups or patterns of letters that may make some sense,

2) Looking for a book in a library; significant variables are groupings of books in library by their system,

3) Dentist; looking systematically so he doesn't miss decay, then has systematic types of treatment for particular degrees of disease,

4) Taking an engine apart; you need to take it apart systematically so that you can put it back together, the variables are the pieces you are taking apart,

5) Computer programs; you need to tell the computer in a systematic order how to perform, the variables would be the lines or series of instructions that make up the program,

6) Classifying things; anything that you classify into any type of order has the significant variables you consider and other that you don't, e.g., plants, colour, type of leaf, flower, height,

7) Finding out what is wrong with a car; you don't take the whole car to pieces to mend a headlamp bulb, so the significant variables are the system of the car that doesn't work, not the whole car.

Friday 25th April.

Last lesson we discussed looking for variables. You now have a list of examples of things we look at carefully and the variables we try to identify in them. Now I want you to think of examples of where you compare by looking for similarities and differences between the variables in things. We try to identify which variables are the same and which are different. We don't look at all the variables do we? We've thought about this before. What sort of variables are we looking when we are comparing? (Proper ones). What are they? (The *ones we are looking at). Yes, but why are you not looking at all possible variables? (Some aren't important). So if you aren't looking at the unimportant variables you must be looking at?......... (Important ones). Good! I did use the words significant variables but important variables is fine.*

Examples given;

1) *Recipe to see if what the recipe requires you have in the cupboard,*
2) *Jig saw where you compare pieces with the picture to find if there are any missing.*
3) *Compare maps to compare where you are by your surrounding with symbols on a map,*
4) *Computers games given in the materials,*
5) *Birds and wild flowers by comparing the sample with pictures in a book to find out the name of your sample,*
6) *Cars if you are going to buy a car compare size, price, mpg, colour etc. between models,*
7) *Weather by comparing weather forecast with the weather that you get,*
8) *Treasure hunt where you compare the clues with you surroundings,*
9) *Your spelling of a word with that in a dictionary.*

Wednesday 30th April.

You have the list of last lessons examples of where you analyse systematically by comparing the important variables you looked for. Try now to think of some more examples where it is very important to compare and note where important variables are similar or different. Examples given by the pupils were;

1) Cups and saucers in a set; they should all be the same or very similar otherwise they don't make a set.

2) Chairs in dining room suite should all be the same.

3) Fruit machines; looking for a winning combination;

4) Signatures; written by the same person the same way always very similar.

5) Letters to addresses; addresses in the same street similar but each house different.

6) Children; those in the same class will have similar age but are usually all different.

Friday 2nd May.

Whilst we have been looking at these sheets we have been talking about analysing what you have been looking at carefully. I have suggested that whilst you have been analysing you have been looking at things systematically, comparing carefully, looking for differences and similarities, matching things etc.. Once you have made all these careful comparisons its all very well. You have an answer. What do you really need to do next? What ought you to do before giving your answer? (Think about it, check what you are doing, study it). I think you have done most of those things in the analysing. (Think about it again). OK what are you doing when you think about it again? Can you think of a word that means going over it again before answering. (Reconsider, revise, rehearse, reflect). Once you have made a decision about something you tend to reflect on it before you say so to someone else. So you are suggesting that before you come up with a final answer you tend to! (think about it, check it, you reconsider it, look at it, try and remember it, revise it, repeat it, reflect on it). Good! Quite a lot to do. Having gone through *all that process. If you are doing the same sort of problem over and over again. What might you get if you are not very careful? (Bored). What is the result of getting bored though? You are probably right you may get bored but in being bored you may get ....? (Lose concentration). Fine you may lose concentration but in so doing you get ....? (Careless). Now if you become careless you start getting things wrong. Not because you don't understand it, not because you can't do it, but just because you become careless. There are many times when I think you get things wrong, not because you can't do them, but because you are careless and don't reflect on what you are doing before replying. Try a few more examples of analysing by comparing significant variables to see if they are the same or different but this time reflect before answering.*

1) *Forgeries; of any type have to look the same but can be seen as forgeries by small differences.*
2) *Prints from famous paintings; copies are similar but are different.*
3) *When trying to match things, e.g., colours or patterns for clothes you look for as few differences as possible.*
4) *Playing bingo; you look for the number given to see if it's on your card.*
5) *Lottery tickets; you look to see if you have a winning combination.*
6) *Cheque book and card; account numbers must match.*
7) *Dates; check to see if it is valid, on cheques, documents, pools etc.*
8) *Telephone; people living in the same area of a town will have the same beginning numbers.*

Wednesday 7th May.

You have gone through three stages in tackling a problem, first analysing. Having analysed the importance of significant parts you compared what you had analysed, e.g., looking to see if diagrams or pictures were the same or different or whether the pictures differed on the computer screen on those significant variables. Then last lesson I suggested that before you wrote anything down you really ought to think about the problem all over again. Reflect on it. Make sure, be more careful. I would like to land up with a definition of what should really be going through your mind when you are looking at something or comparing two different things. You don't always know what it is you will be analysing. It may be a general pattern, it may be differences, what ever. Up to a point you have to create your own strategy. You have to make a conscientious effort to look at something and analyse it. When you analyse you must be systematic. It is no good going from one thing to another. Its no good drifting from one thing to another. You must look at it quite carefully and go through it systematically. For example the clueless crosswords. Its no good going from one letter or number to another. You have to go through it systematically line by line so you don't miss anything. Like anagrams and word searches. Not just larking around and looking at whatever takes your fancy. So if you are trying to look carefully you should do it in a systematic way. One of the things you then have to do is only look at the things that really matter. Its no good looking at lots of things that don't matter. I tried to get you to think of lots of examples of your own where you tried to ignore things that distract and don't matter very much. You looked for what? what was the word I tried to get you to use. (variables). Good! variables was the second word. What was the other word I used that meant looking at the important variables beginning with 's'. (suitable). Not really, (specific), could be, (those that matter). I like that but it isn't what I was after but we will put it down. It started 'sig' .... (significant), good! well done! What we are saying is that when we come up against a comparison problem where we are looking for differences, or comparing things then, using your phrases, we should have a strategy for looking systematically only at the variables that matter. Your next step is to compare them. So the next thing is to compare. The first thing you do is analyse and the next thing is to compare. Once you have systematically identified the variables that matter then you compare the significant variables between one picture, diagram, experiment and the other. Having done the analysis and comparison you then reflect. Look back at it before you answer, to make sure you were right, to be sure you haven't been silly or careless. So now, when ever you come across a comparison problem, looking for differences, similarities etc; you identify systematically the variables that matter, compare those variables, then reflect on what you have done before answering. So there are three stages summarised as analysing, comparing and reflecting.

NB the following was now on the board:

Analysing; systematically identifying the variables that matter,

Comparing; comparing only the variables that matter,

Reflecting; reviewing solutions before answering.

Now what we have been trying to do is produce a system for your thinking. This can be summarised as ARC now see if you can come up with three other words that are easier to remember that will prompt *you to remember ARC, and so analyse, compare and reflect, and then hopefully all that went on the board behind me.*

Group 2: reorganization.

Friday 9th May

We took a long time considering analysing, comparing and reflection when you were looking at things like spot the difference etc.. Now I want to look at another group of activities you have been doing like anagrams, shuffled sentences, sentences where there are gaps and you have to put the gaps into a different place to get the sentence to make sense, and where I have given you sets of instructions for an experiment and you have had to put them in the correct order. Now if you are trying to solve any one of those what is the first thing you have to try and do? Lets just take one, anagrams. It might be easier for you to focus your attention on just one of them. What is the first thing you try and do? (Solve the word). That might be true of a very short word but not of the longer ones. (Groups of letters). Fine! you look for beginnings and endings of words that may make some sense. (Vowels). Yes vowels help you to make some sense out of the jumble of letters. (Try to think of lots of words that contain the same number of letters, then see if any you think of could use the letters you have). Good! that's one way of doing it. Do you always look just at individual letters? (No you put letters together sometimes). When you are looking for a small group of letters that make sense, or vowels, or anything like that I think you could summarise it by saying you look for?......... (Groups, order, pattern, arrangement, sequence). Great! all those are good words. Which one do you think is best? You are trying to find groups of letters that make some sense. Which of those words do you prefer. (Majority for pattern). Good you look for patterns of letters that could make some sense so you sort the remaining letters more easily. You are not looking for any letters in particular. You are looking at a jumble of letters, and in them, a pattern that could make sense. Right what do you do with these groups of letters once you've got them? (Sort them). Yes but to sort them you must have done what to the original order of the letters? (Reorganised them). Why do you think I tried to get you to think of what you did before reorganising the letters? (Too difficult). Why? (Short words are easy but lots of letters make it difficult). Why? (It takes too long to reorganise them all ways). Good! You can't reorganise all the letters in all possible combinations until a word comes up that works. Short words are fine but longer words would need a computer. So to solve anagrams or similar problems you look for patterns that make sense, reorganise them too see if you can make a word. Then what? What if you don't get a word? (Give up). No come on. (Look at the letters again). What for? (New groups). Yes but what word did we use? (Patterns). Very good! Right that will do for today except try to think before next lesson of examples of where you look for patterns in every day live.

Examples given by pupils;

cars by variation in patterns, types of buildings, flower types, peoples faces, words, whether things are up right, e.g., buildings, recognise one's own house in a row of similar ones, recognising anything, keys or locks.

Wednesday 14th May.

Now last lesson we tried to see how we solved anagrams. Now the shuffled sentences are solved the same way. Looking for patterns of words that make sense and then trying to fit in the other words to make a sentence. If that fails you look for new patterns. The gaps in sentences are similar. You move the gap backwards and forwards to see if you can make a recognisable pattern of a word. Some times you get a word but that doesn't work elsewhere in the sentence. So even recognisable patterns are not always correct. Now today I want you to write down examples of where you look for recognisable patterns. That means more than just the pattern itself. I'll give you a couple of examples. Road signs. Now they are patterns that we see every day and recognise and they give us a great deal of information. Reading. Words are recognisable patterns that we 'see' and understand every day. Since Chenobyl I hope you would all recognise a radiation sign, another pattern that we have stored. We organise what we see to the patterns in our heads. I want you now to think of any examples of your own and write them down.

Examples from pupils;

Flags of countries, red for danger, piano keyboard, emblem, e.g., rose for England,computer keyboard, peoples characteristics, e.g., Tom and Jerry, writing characteristics, patterns of letters, e.g., alphabet, logos, known telephone numbers, signatures, known number plates on cars, pop groups that are instantly recognisable, traffic lights, types of writing, e.g., lists, letters, work cards, television adverts, clothes fashionable or not, medals, people's voices, design diagrams, spelling, e.g.,

misspelt words, musical notes, map signs, short forms of longer words, e.g., cm, km, word searches, walking and running style.

Friday 16th May

Today I want to take our thinking about analysing patterns a little further. I asked you to think of things in which you recognise patterns. We have many patterns in our heads that mean something to us. I asked you to think of as many as you could. I will read you the list that you contributed. Some of you said the same things and of course they are only included once. The list was as follows: (list above read with some embellishments). Now the next stage is to try to think of patterns that we have power to alter or patterns that do alter. One example comes from the list I've given you. Traffic lights. That pattern changes and the change in pattern is significant. Now I want you to think of patterns that change or we can change. What things to we reorganise in our lives?

Examples given;

1) *The way voices change, e.g., temper, soothing, grumpy etc.,*
2) *Changes of tone when motor bikes change gear,*
3) *Plants growing to a set pattern, i.e., seed, plant, flower, seed,*
4) *Aging process in people follows a set pattern,*
5) *Speed bank; patterns of instructions for set outcomes,*
6) *Analog watch; the hands position is changing all the time,*
7) *Telephone numbers; various codes denote particular areas,*
8) *Writing styles alter as you get older,*
9) *Change in tone of bath water as it fills,*
10) *Musical notes make a pattern that can be altered and the music changes,*

11) Changing patterns of a computer game, as you do well or not different patterns are produced,

12) Altering words to fit a tune,

13) Speech, dialects etc.,

14) People change clothes but are still recognisable,

15) Changing hair styles,

16) Alphabets in different languages,

17) Changing colours of make up,

18) Spelling mistakes,

19) The same meaning in different languages are usually different words or the same word may have totally different meanings,

20) Changing the tune of a door bell,

21) Transformers (the child type that can be changed from one thing to another, e.g., rocket to robot).

Wednesday 21st May.

Today is the last step in this group of activities in which you need to identify and reorganize patterns. Ok so we have identified some patterns that make sense. We've reorganized those patterns to try to produce a solution. Then what! What if we haven't an answer to the problem what then? (Give up). Not immediately surely. (Try again). What word would you use if you tried again and again until you got a solution. (Repeating). Good that will do fine. Now lets write down a summary of how we go about solving this type of reorganizing problem.

Identification of patterns that make some sense,

Reorganization of those patterns trying to produce a solution.

Repeating identification and reorganization of patterns that make sence until the problem is solved.

Group 3: disembedding.

The final group of activities, i.e., disembedding was done in the same way. A summary of the pupils' responses and the final short three line synopsis (similar to immediately above) is given in part 3 below.

Part 3

The summary was given to pupils as a revision homework immediately before post testing.

In the first group of activities I had tried to get you to look at comparison problems by ANALYSING, COMPARING AND REFLECTING.

ANALYSING.

Some of the words we came up with when analysing systematically and carefully were; look, shapes, study, careful, compare, similarities, differences, observe, examine, analyse, looking systematically, characters: some of the examples you gave were;

1) Tinned food, looking at labels for contents eg. additives, sugar, eat by date etc.,
2) Look at recipes to see what is required for a meal: you might then compare to see if you have what was required by in the recipe in the cupboard,
3) Soap to see if it contains things to which someone might be allergic,

4) *Instructions on things bought, e.g., seeds, models, dress patterns,*
5) *Dictionaries and indexes to find references to information required, telephone book for telephone numbers,*
6) *Computer programs to find sources of errors,*
7) *Looking through work and answers to see if there are any mistakes,*
8) *Looking for traffic before crossing the road.*

Some of the words we used when we looked for significant variables were; systematically, analysing, characters, similarities, differences, change, alter, transform, vary, variables, important variables, significant variables and some of the examples you gave were;

1) *Anagrams: significant variables are groups or patterns of letters that may make some sense,*
2) *Looking for a book in a library; significant variables are groupings of books in library by their system,*
3) *Dentist; looking systematically so he doesn't miss decay, then has systematic types of treatment for particular degrees of disease,*
4) *Taking an engine apart; you need to take is apart systematically so that you can put it back together, the variables are the pieces you a taking apart,*
5) *Computer programs; you need to tell the computer in a systematic order how to perform, the variables would be the lines or series of instructions that make up the program,*

6) *Classifying things; anything that you classify into any type of order has the significant variables you consider and other that you don't, e.g., plants, colour, type of leaf, flower, height,*
7) *Finding out what is wrong with a car; you don't take the whole car to pieces to mend a headlamp bulb, so the significant variables are not the whole car, but the system of the car that doesn't work.*

COMPARING.

The next stage was comparing and some of the words used here were; changes, alter, transform, vary, variables. When we compare we are looking for similarities and differences. Examples of where we look for similarities and differences in every day life were;

1) *Recipe to see if what the recipe requires you have in the cupboard,*
2) *Jig saw where you compare pieces with the picture to find if there are any missing.*
3) *Compare maps to compare where you are by your surrounding with symbols on a map,*
4) *Computers games given in the activities,*
5) *Birds and wild flowers by comparing the sample with pictures in a book to find out the name of your sample,*
6) *Cars if you are going to buy a car compare size, prize, m.p.g., colour etc. between models,*

7) Weather by comparing weather forecast with the weather that you get,

8) Treasure hunt where you compare the clues with you surroundings,

9) Your spelling of a word with that in a dictionary.

Next we looked at comparing the important variables and noted what these variables were. Here are some examples you gave.

1) Comparing humans with other animal; number of legs, eyes, hair, teeth, diet, size etc,

2) Walking or getting a lift home; length of time, laziness, cost, ease, weather,

3) Crisps; cost, flavour, type, weight, make, influence of TV,

4) Moods; good days dad comes in smiling, chatty, doesn't slam doors, bad day dad is grumpy, sour faced, rude and bangs doors,

5) Drinks; flavour, cost, size, colour, alcoholic, type of container, additives,

6) Televisions; colour/black and white, size, cost, rent/buy, remote control, ear phone plug, computer input,

7) Sweets; type, colour, size, cost, flavour, what your friends like, what you like,

8) People; height, weight, sex, colour, religion, age, status, personality, hair colour, type of clothes worn.

REFLECTING

Having compared carefully all the significant variables we then decided that we should reflect on what we had done before answering and so landed up with;

###################

Analysing; systematically identifying the variables that matter,
Comparing; comparing only the variables that matter,
Reflecting; reviewing solutions before answering.

###################

The next sort of problem we tried to solve and think about our thinking were those that needed IDENTIFICATION of patterns and REORGANISING them REPEATING if necessary until a solution is found.

IDENTIFICATION OF PATTERNS

Examples of the words we used when thinking about recognising patterns were; solve, groups, vowels, letters together, order, pattern, arrangement, sequence, sort, reorganise, look again, new groups.

Examples you gave of where we recognise patterns in every day life were; flags of countries, red for danger, piano keyboard, emblem, e.g., rose for England, cars by variation in patterns, computer keyboard, peoples characteristics, e.g., Tom and Jerry, writing characteristics, types of buildings, patters of letters, e.g., alphabet, logos, known telephone numbers, signatures, known number plates on cars, pop groups that are instantly recognisable, flower types, traffic lights, types of writing, e.g., *lists, letters, work cards, television adverts, clothes fashionable or not, medals, people's voices, design diagrams, spelling, e.g., misspelt words, musical notes, map signs, short forms of longer words, e.g., cm. km., word searches, walking and running style.*

REORGANISING PATTERNS

Next we tried to find examples of where we reorganise patterns in our lives. The examples you gave were;

1. *The way voices change, e.g., temper, soothing, grumpy etc.,*
2. *Changes of tone when motor bikes change gear,*
3. *Plants growing to a set pattern, i.e., seed, plant, flower, seed,*
4. *Aging process in people follows a set pattern,*
5. *Speed bank; patterns of instructions for set outcomes,*
6. *Analog watch; the hands position is changing all the time,*
7. *Telephone numbers; various codes denote particular areas,*
8. *Writing styles alter as you get older,*
9. *Change in tone of bath water as it fills,*
10. *Musical notes make a pattern that can be altered and the music changes,*
11. *Changing patterns of a computer game, as you do well or not different patterns are produced,*
12. *Altering words to fit a tune,*
13. *Speech, dialects etc.,*
14. *People change clothes but are still recognisable,*
15. *Changing hair styles,*

16. Alphabets in different languages,
17. Changing colours of make up,
18. Spelling mistakes,
19. The same meaning in different languages are usually different words or the same word may have totally different meanings,
20. Changing the tune of a door bell,
21. Transformers (the child type that can be changed from one thing to another, e.g., rocket to robot).

REPEATING

It is necessary to repeat the identification and reorganising of patterns until a solution is found.

####################

Identification; of patterns that make some sense,
Reorganisation; of those patterns try to produce a solution,
Repeat; identification and reorganisation of patterns that make sence until problem is solved.

####################

In the final sort of problem we tried looking for simple patterns inside complex patterns by SEPARATING recognisable bits from the complex then RECOMBINING systematically until OTHER COMBINATIONS had been found.

Examples of words we used when looking for simple patterns hidden in more complex ones were; separating, looking carefully, changing the way you look, reorganising, hidden, one thing inside another, disguised, not easily recognised, cheating, concealed, simple, complicated, restructure, difficult to see, combined, same thing used twice for different things, recombine.

Examples you gave of where we SEPARATE the simple from the complex;

1) papers in filing cabinets,
2) my house in a street, town, county,
3) sparking plug part of an engine, part of a car,
4) I'm part of a tutor group, part of a year,
5) Tewkesbury is part of Gloucestershire, part of England, Europe, World,
6) some ladders can be made into steps,
7) multipurpose tools can be made into screwdrivers, spanners etc.,
8) looking for someone in a crowd,
9) finding your car in a car park,
10) finding someone on a beach,
11) looking words up in a dictionary,
12) finding places on a map,
13) finding a room in a large school,
14) finding your bus route in a timetable,

RECOMBINING

Often there is more than one way of organising a complex pattern of things. So it is necessary to RECOMBINE the bits in a complex pattern to see if there are any other important patterns.

NEW COMBINATIONS.

Examples of where we recombine old patterns to find new patterns were;

1) transformers (the pupil robot/lorry type),

2) I'm part of a tutor group, and part of a school house,

3) daddy is daddy, uncle, husband, man, lorry driver,

4) a set of clothes can be worn in many different combinations,

5) some groups of letters can be recombined to make different words,

6) cars using parts of the same road going to and from different places,

######################

Separating;	***finding smaller parts that make sense from a large complex whole,***
Recombining;	***to make,***
New combinations;	***that also make sense.***

######################

Appendix 5: Final Study Results

TABLE APPENDIX 5-1: MEANS AND STANDARD DEVIATIONS FOR PRE- AND POST-TEST SCORES ON GROUP EMBEDDED FIGURES TEST BETWEEN EXPERIMENTAL GROUPS AND CONTROLS.

		Pre-test		Post-test		Difference pre - post	
	N	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}_2-\bar{X}_1$	σ
Expt. gp1	20	5.40	3.72	12.15	5.27	6.75	4.27
Expt. gp2a	23	5.13	4.03	13.30	4.20	8.17	2.64
Expt. gp2b	19	3.84	3.32	10.42	4.67	6.58	2.97
Expt. gps2a+2b	42	4.55	3.74	11.98	4.63	7.45	2.87
Control gp1	21	3.33	2.20	5.62	3.22	2.29	1.77
Control gp2	20	4.50	3.83	6.80	4.572	2.30	3.11
Control 1+2	41	3.90	3.12	6.20	3.93	2.29	2.48

TABLE APPENDIX 5-2: MEANS AND STANDARD DEVIATIONS FOR PRE- AND POST-TEST SCORES ON SCIENCE REASONING TASK II BETWEEN EXPERIMENTAL GROUPS AND CONTROLS.

		Pre-test		Post-test		Difference pre - post	
	N	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}_2-\bar{X}_1$	σ
Expt. gp1	20	3.65	0.99	4.35	0.93	0.70	0.87
Expt. gp2a	23	3.39	0.66	4.65	0.98	1.26	0.86
Expt. gp2b	19	3.58	0.96	4.63	0.95	1.05	0.52
Expt. gps2a+2b	42	3.48	0.80	6.64	0.96	1.16	0.73
Control gp1	21	2.91	1.14	3.29	1.31	0.38	0.92
Control gp2	20	2.75	0.91	3.00	1.34	0.25	1.07
Control 1+2	41	2.83	1.02	3.15	1.32	0.32	0.99

TABLE APPENDIX 5-3: MEANS AND STANDARD DEVIATIONS FOR SCORES ON CLASS SCIENCE TEST BETWEEN EXPERIMENTAL GROUPS AND CONTROLS.

	N	Post test	
		$\bar{X}$	σ
Expt. gp1	20	76.55	13.77
Expt. gp2a	20	71.26	12.26
Expt. gp2b	20	70.05	13.90
Control gp1	21	71.19	9.16
Control gp2	20	65.30	14.94
Control 1+2	41	68.32	12.53

TABLE APPENDIX 5-4: t-TESTS, EFFECT SIZES AND PERCENTILES BETWEEN EXPT.GPS. AND CONTROLS ON THE DIFFERENCES BETWEEN PRE AND POST TEST SCORES ON THE GROUP EMBEDDED FIGURES TEST, SCIENCE REASONING TASK II & CLASS SCIENCE TEST.

	N	Expt.gp. 1			Expt.gp. 2a			Expt.gp 2b		
		t-test	sz.e	%le	t-test	sz.e	%le	t-test	sz.e	%le
Group Embedded Figures										
ctr 1	20	10.14$_a$	1.18	88%	19.79$_a$	1.68	95%	12.89$_a$	1.24	89%
ctr 2	21	8.66$_a$	1.01	84%	15.41$_a$	1.41	92%	10.08$_a$	1.04	85%
Science Reasoning Task II.										
ctr 1	20	2.38$_c$	0.29	61%	6.83$_a$	0.84	80%	5.81$_a$	0.61	73%
ctr 2	21	3.03$_b$	0.42	66%	7.14$_a$	1.00	84%	6.12$_a$	0.76	78%
Class Science Test.										
ctr 1	20	1.45$_a$			2.14$_a$			-0.31		
ctr 2	21	2.48$_d$			1.44			1.03		

where; sz.e = size effect, %le = percentile, $_a$ $p<0.005$, $_b$ $p<0.006$, $_c$ $p<0.025$, $_d$ $p<0.01$, e $p<0.125$
Expt. gp. 1 N= 20, Expt. gp 2a N=23, Expt. gp. 2b N=19

For Diagrammatic representation of size effects after Rosenthal (1978) and Smith & Glass (1977, 1981) see diagrams appendix 5-1 to 5-4.

FIGURE APPENDIX 5-1: SHADED AREA SHOWS 82% OF THE EXPERIMENTAL GROUP 1 ARE BETTER THAN THE MEAN OF THE CONTROL GROUP ON THE GROUP EMBEDDED FIGURES TEST.

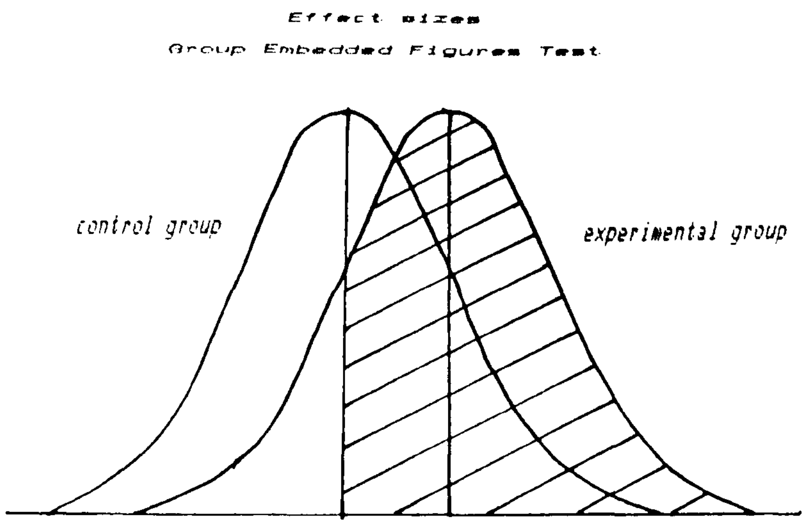


FIGURE APPENDIX 5-2: SHADED AREA SHOWS 91% OF THE EXPERIMENTAL GROUPS 2a+2b ARE BETTER THAN THE MEAN OF THE CONTROL GROUP ON THE GROUP EMBEDDED FIGURES TEST.

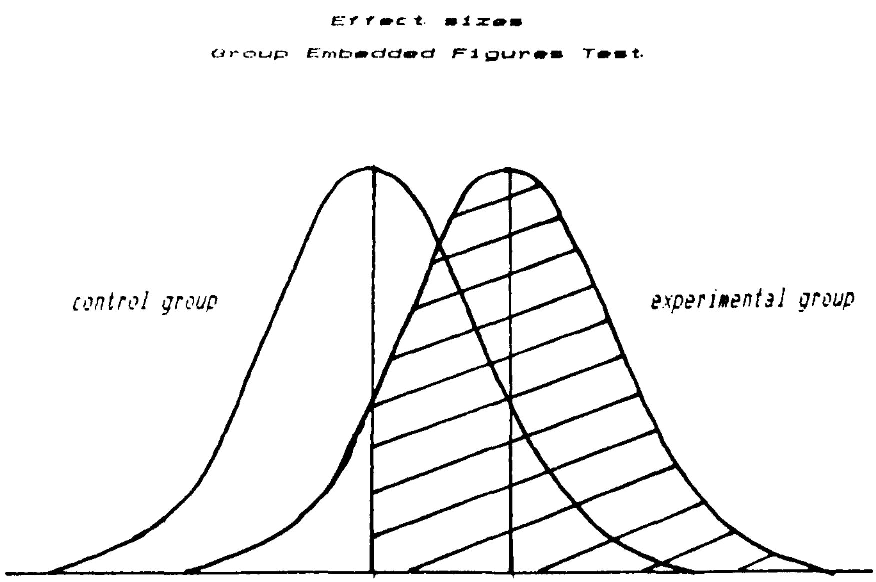


FIGURE APPENDIX 5-3: SHADED AREA SHOWS 64% OF THE EXPERIMENTAL GROUP 1 ARE BETTER THAN THE MEAN OF THE CONTROL GROUP ON SCIENCE REASONING TASK II.

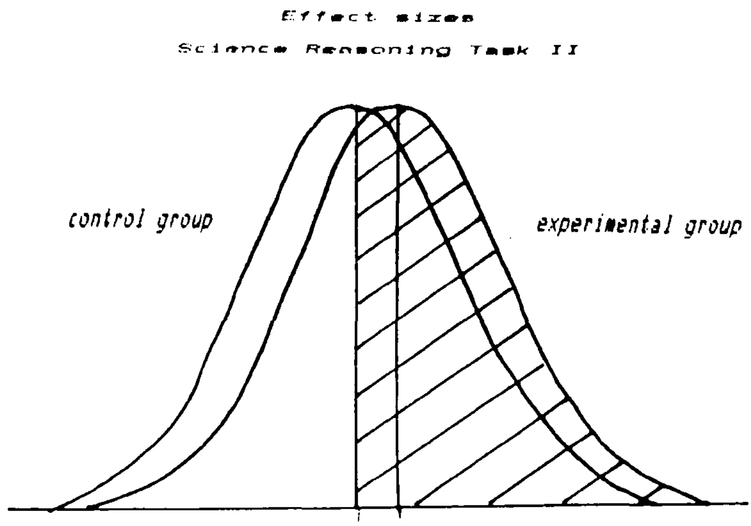
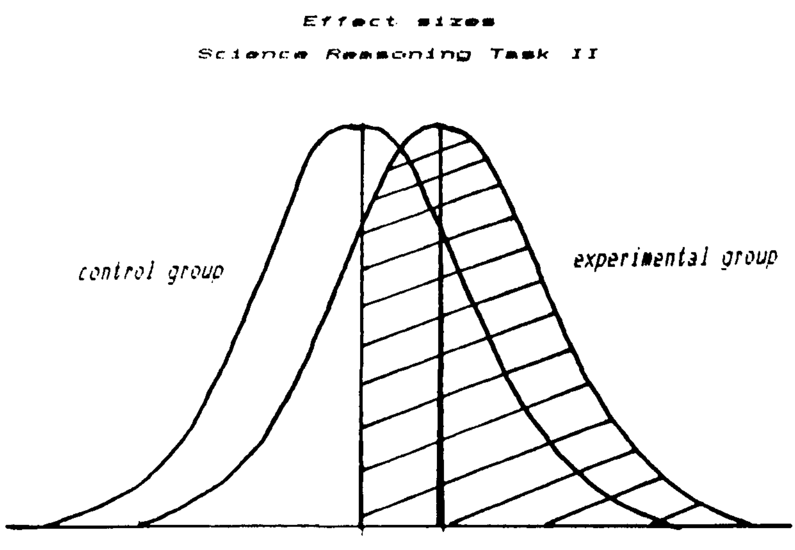


FIGURE APPENDIX 5-4: SHADED AREA SHOWS 79% OF THE EXPERIMENTAL GROUP 2a+2b ARE BETTER THAN THE MEAN OF THE CONTROL GROUP ON SCIENCE REASONING TASK II.



Appendix 6: Kolgromov-Smirnov significance table.

This table of significance values for D was calculated using the formula in Guilford (1973) page 226;

$$D = V \quad \frac{N1 + N2}{N1 \times N2}$$

where V = 1.22 for significance at 0.100
V = 1.36 " " " 0.050
V = 1.63 " " " 0.010
V = 1.95 " " " 0.001

Sig = 0.1

N2 =	18	19	20	21	22	23	24	25	26	27
N1 = 17	0.4126	0.4073	0.4025	0.3980	0.3940	0.3902	0.3867	0.3835	0.3805	0.3777
N1 = 18	0.4067	0.4013	0.3964	0.3919	0.3877	0.3839	0.3804	0.3771	0.3741	0.3712
N1 = 19	0.4013	0.3958	0.3908	0.3863	0.3821	0.3782	0.3746	0.3713	0.3682	0.3653
N1 = 20	0.3964	0.3908	0.3858	0.3812	0.3769	0.3730	0.3694	0.3660	0.3629	0.3599
N1 = 21	0.3919	0.3863	0.3812	0.3765	0.3722	0.3682	0.3645	0.3611	0.3579	0.3550
N1 = 22	0.3877	0.3821	0.3769	0.3722	0.3678	0.3638	0.3601	0.3566	0.3534	0.3504
N1 = 23	0.3839	0.3782	0.3730	0.3682	0.3638	0.3598	0.3560	0.3525	0.3492	0.3462
N1 = 24	0.3804	0.3746	0.3694	0.3645	0.3601	0.3560	0.3522	0.3486	0.3453	0.3423
N1 = 25	0.3771	0.3713	0.3660	0.3611	0.3566	0.3525	0.3486	0.3451	0.3417	0.3386
N1 = 26	0.3741	0.3682	0.3629	0.3579	0.3534	0.3492	0.3453	0.3417	0.3384	0.3352
N1 = 27	0.3712	0.3653	0.3599	0.3550	0.3504	0.3462	0.3423	0.3386	0.3352	0.3320
N1 = 28	0.3686	0.3626	0.3572	0.3522	0.3476	0.3433	0.3394	0.3357	0.3323	0.3291
N1 = 29	0.3661	0.3601	0.3546	0.3496	0.3449	0.3406	0.3367	0.3330	0.3295	0.3263
N1 = 30	0.3637	0.3577	0.3522	0.3471	0.3424	0.3381	0.3341	0.3304	0.3269	0.3236
N1 = 31	0.3615	0.3555	0.3499	0.3448	0.3401	0.3357	0.3317	0.3279	0.3244	0.3212
N1 = 32	0.3594	0.3533	0.3478	0.3426	0.3379	0.3335	0.3294	0.3257	0.3221	0.3188
N1 = 33	0.3575	0.3513	0.3457	0.3406	0.3358	0.3314	0.3273	0.3235	0.3199	0.3166
N1 = 34	0.3556	0.3494	0.3438	0.3386	0.3338	0.3294	0.3253	0.3214	0.3178	0.3145
N1 = 35	0.3539	0.3477	0.3420	0.3368	0.3319	0.3275	0.3233	0.3195	0.3159	0.3125
N1 = 36	0.3522	0.3459	0.3402	0.3350	0.3301	0.3257	0.3215	0.3176	0.3140	0.3106
N1 = 37	0.3506	0.3443	0.3386	0.3333	0.3285	0.3239	0.3198	0.3159	0.3122	0.3088
N1 = 38	0.3491	0.3428	0.3370	0.3317	0.3268	0.3223	0.3181	0.3142	0.3105	0.3071
N1 = 39	0.3476	0.3413	0.3355	0.3302	0.3253	0.3207	0.3165	0.3126	0.3089	0.3054
N1 = 40	0.3463	0.3399	0.3341	0.3288	0.3238	0.3193	0.3150	0.3110	0.3073	0.3039
N1 = 41	0.3450	0.3386	0.3327	0.3274	0.3224	0.3178	0.3136	0.3096	0.3059	0.3024
N1 = 42	0.3437	0.3373	0.3314	0.3261	0.3211	0.3165	0.3122	0.3082	0.3044	0.3009
N1 = 43	0.3425	0.3361	0.3302	0.3248	0.3198	0.3152	0.3109	0.3068	0.3031	0.2996
N1 = 44	0.3413	0.3349	0.3290	0.3236	0.3186	0.3139	0.3096	0.3056	0.3018	0.2983
N1 = 45	0.3402	0.3338	0.3279	0.3224	0.3174	0.3127	0.3084	0.3043	0.3005	0.2970
N1 = 46	0.3392	0.3327	0.3268	0.3213	0.3162	0.3116	0.3072	0.3031	0.2993	0.2958
N1 = 47	0.3382	0.3317	0.3257	0.3202	0.3152	0.3105	0.3061	0.3020	0.2982	0.2946

Sig = 0.05

N2 =	18	19	20	21	22	23	24	25	26	27
N1 = 17	0.4600	0.4540	0.4486	0.4437	0.4392	0.4350	0.4311	0.4275	0.4242	0.4211
N1 = 18	0.4533	0.4473	0.4419	0.4368	0.4322	0.4280	0.4241	0.4204	0.4170	0.4138
N1 = 19	0.4473	0.4412	0.4357	0.4306	0.4259	0.4216	0.4176	0.4139	0.4105	0.4072
N1 = 20	0.4419	0.4357	0.4301	0.4249	0.4202	0.4158	0.4118	0.4080	0.4045	0.4012
N1 = 21	0.4368	0.4306	0.4249	0.4197	0.4149	0.4105	0.4064	0.4026	0.3990	0.3957
N1 = 22	0.4322	0.4259	0.4202	0.4149	0.4101	0.4056	0.4014	0.3976	0.3940	0.3906
N1 = 23	0.4280	0.4216	0.4158	0.4105	0.4056	0.4010	0.3968	0.3929	0.3893	0.3859
N1 = 24	0.4241	0.4176	0.4118	0.4064	0.4014	0.3968	0.3926	0.3887	0.3850	0.3815
N1 = 25	0.4204	0.4139	0.4080	0.4026	0.3976	0.3929	0.3887	0.3847	0.3809	0.3775
N1 = 26	0.4170	0.4105	0.4045	0.3990	0.3940	0.3893	0.3850	0.3809	0.3772	0.3737
N1 = 27	0.4138	0.4072	0.4012	0.3957	0.3906	0.3859	0.3815	0.3775	0.3737	0.3701
N1 = 28	0.4109	0.4042	0.3982	0.3926	0.3875	0.3827	0.3783	0.3742	0.3704	0.3668
N1 = 29	0.4081	0.4014	0.3953	0.3897	0.3845	0.3797	0.3753	0.3712	0.3673	0.3637
N1 = 30	0.4055	0.3987	0.3926	0.3869	0.3817	0.3769	0.3725	0.3683	0.3644	0.3608
N1 = 31	0.4030	0.3962	0.3901	0.3844	0.3791	0.3743	0.3698	0.3656	0.3617	0.3580
N1 = 32	0.4007	0.3939	0.3877	0.3819	0.3767	0.3718	0.3672	0.3630	0.3591	0.3554
N1 = 33	0.3985	0.3917	0.3854	0.3796	0.3743	0.3694	0.3648	0.3606	0.3566	0.3529
N1 = 34	0.3964	0.3895	0.3832	0.3775	0.3721	0.3672	0.3626	0.3583	0.3543	0.3506
N1 = 35	0.3945	0.3875	0.3812	0.3754	0.3700	0.3651	0.3604	0.3561	0.3521	0.3484
N1 = 36	0.3926	0.3856	0.3793	0.3734	0.3680	0.3630	0.3584	0.3541	0.3500	0.3462
N1 = 37	0.3908	0.3838	0.3775	0.3716	0.3661	0.3611	0.3564	0.3521	0.3480	0.3442
N1 = 38	0.3891	0.3821	0.3757	0.3698	0.3643	0.3593	0.3546	0.3502	0.3461	0.3423
N1 = 39	0.3875	0.3805	0.3740	0.3681	0.3626	0.3576	0.3528	0.3484	0.3443	0.3405
N1 = 40	0.3860	0.3789	0.3725	0.3665	0.3610	0.3559	0.3512	0.3467	0.3426	0.3387
N1 = 41	0.3845	0.3774	0.3709	0.3649	0.3594	0.3543	0.3495	0.3451	0.3410	0.3371
N1 = 42	0.3831	0.3760	0.3695	0.3635	0.3579	0.3528	0.3480	0.3435	0.3394	0.3355
N1 = 43	0.3818	0.3746	0.3681	0.3621	0.3565	0.3513	0.3465	0.3420	0.3379	0.3339
N1 = 44	0.3805	0.3733	0.3668	0.3607	0.3551	0.3499	0.3451	0.3406	0.3364	0.3325
N1 = 45	0.3793	0.3721	0.3655	0.3594	0.3538	0.3486	0.3438	0.3392	0.3350	0.3311
N1 = 46	0.3781	0.3709	0.3643	0.3582	0.3525	0.3473	0.3425	0.3379	0.3337	0.3297
N1 = 47	0.3770	0.3697	0.3631	0.3570	0.3513	0.3461	0.3412	0.3367	0.3324	0.3284

Sig = 0.01

N2 =	18	19	20	21	22	23	24	25	26	27
N1 = 17	0.5513	0.5442	0.5377	0.5318	0.5264	0.5213	0.5167	0.5124	0.5084	0.5047
N1 = 18	0.5433	0.5361	0.5296	0.5236	0.5180	0.5130	0.5082	0.5039	0.4998	0.4960
N1 = 19	0.5361	0.5288	0.5222	0.5161	0.5105	0.5053	0.5005	0.4961	0.4920	0.4881
N1 = 20	0.5296	0.5222	0.5155	0.5093	0.5036	0.4984	0.4935	0.4890	0.4848	0.4809
N1 = 21	0.5236	0.5161	0.5093	0.5030	0.4973	0.4920	0.4871	0.4825	0.4782	0.4743
N1 = 22	0.5180	0.5105	0.5036	0.4973	0.4915	0.4861	0.4811	0.4765	0.4722	0.4682
N1 = 23	0.5130	0.5053	0.4984	0.4920	0.4861	0.4807	0.4756	0.4709	0.4666	0.4625
N1 = 24	0.5082	0.5005	0.4935	0.4871	0.4811	0.4756	0.4705	0.4658	0.4614	0.4573
N1 = 25	0.5039	0.4961	0.4890	0.4825	0.4765	0.4709	0.4658	0.4610	0.4566	0.4524
N1 = 26	0.4998	0.4920	0.4848	0.4782	0.4722	0.4666	0.4614	0.4566	0.4521	0.4479
N1 = 27	0.4960	0.4881	0.4809	0.4743	0.4682	0.4625	0.4573	0.4524	0.4479	0.4436
N1 = 28	0.4924	0.4845	0.4772	0.4705	0.4644	0.4587	0.4534	0.4485	0.4439	0.4397
N1 = 29	0.4891	0.4811	0.4738	0.4671	0.4609	0.4551	0.4498	0.4449	0.4402	0.4359
N1 = 30	0.4860	0.4779	0.4705	0.4638	0.4575	0.4518	0.4464	0.4414	0.4368	0.4324
N1 = 31	0.4830	0.4749	0.4675	0.4607	0.4544	0.4486	0.4432	0.4382	0.4335	0.4291
N1 = 32	0.4802	0.4721	0.4646	0.4578	0.4514	0.4456	0.4402	0.4351	0.4304	0.4259
N1 = 33	0.4776	0.4694	0.4619	0.4550	0.4486	0.4428	0.4373	0.4322	0.4274	0.4230
N1 = 34	0.4751	0.4669	0.4593	0.4524	0.4460	0.4401	0.4346	0.4294	0.4247	0.4202
N1 = 35	0.4728	0.4645	0.4569	0.4499	0.4435	0.4375	0.4320	0.4268	0.4220	0.4175
N1 = 36	0.4705	0.4622	0.4546	0.4476	0.4411	0.4351	0.4295	0.4244	0.4195	0.4150
N1 = 37	0.4684	0.4600	0.4524	0.4453	0.4388	0.4328	0.4272	0.4220	0.4171	0.4126
N1 = 38	0.4664	0.4580	0.4503	0.4432	0.4367	0.4306	0.4250	0.4198	0.4149	0.4103
N1 = 39	0.4645	0.4560	0.4483	0.4412	0.4346	0.4285	0.4229	0.4176	0.4127	0.4081
N1 = 40	0.4626	0.4542	0.4464	0.4393	0.4327	0.4265	0.4209	0.4156	0.4106	0.4060
N1 = 41	0.4609	0.4524	0.4446	0.4374	0.4308	0.4246	0.4189	0.4136	0.4086	0.4040
N1 = 42	0.4592	0.4507	0.4428	0.4356	0.4290	0.4228	0.4171	0.4117	0.4068	0.4021
N1 = 43	0.4576	0.4490	0.4412	0.4339	0.4273	0.4211	0.4153	0.4100	0.4049	0.4002
N1 = 44	0.4561	0.4475	0.4396	0.4323	0.4256	0.4194	0.4136	0.4082	0.4032	0.3985
N1 = 45	0.4546	0.4460	0.4380	0.4308	0.4240	0.4178	0.4120	0.4066	0.4015	0.3968
N1 = 46	0.4532	0.4445	0.4366	0.4293	0.4225	0.4163	0.4104	0.4050	0.3999	0.3952
N1 = 47	0.4518	0.4431	0.4352	0.4278	0.4211	0.4148	0.4089	0.4035	0.3984	0.3936

Sig = 0.001

N2 =	18	19	20	21	22	23	24	25	26	27
N1 = 17	0.6595	0.6510	0.6433	0.6362	0.6297	0.6237	0.6182	0.6130	0.6082	0.6037
N1 = 18	0.6500	0.6414	0.6335	0.6264	0.6198	0.6137	0.6080	0.6028	0.5979	0.5934
N1 = 19	0.6414	0.6327	0.6247	0.6174	0.6107	0.6045	0.5988	0.5935	0.5885	0.5839
N1 = 20	0.6335	0.6247	0.6166	0.6093	0.6025	0.5962	0.5904	0.5850	0.5800	0.5753
N1 = 21	0.6264	0.6174	0.6093	0.6018	0.5949	0.5886	0.5827	0.5772	0.5721	0.5674
N1 = 22	0.6198	0.6107	0.6025	0.5949	0.5879	0.5815	0.5756	0.5700	0.5649	0.5601
N1 = 23	0.6137	0.6045	0.5962	0.5886	0.5815	0.5750	0.5690	0.5634	0.5582	0.5533
N1 = 24	0.6080	0.5988	0.5904	0.5827	0.5756	0.5690	0.5629	0.5573	0.5520	0.5471
N1 = 25	0.6028	0.5935	0.5850	0.5772	0.5700	0.5634	0.5573	0.5515	0.5462	0.5412
N1 = 26	0.5979	0.5885	0.5800	0.5721	0.5649	0.5582	0.5520	0.5462	0.5408	0.5358
N1 = 27	0.5934	0.5839	0.5753	0.5674	0.5601	0.5533	0.5471	0.5412	0.5358	0.5307
N1 = 28	0.5891	0.5796	0.5709	0.5629	0.5556	0.5488	0.5424	0.5366	0.5311	0.5260
N1 = 29	0.5851	0.5755	0.5668	0.5587	0.5513	0.5445	0.5381	0.5322	0.5267	0.5215
N1 = 30	0.5814	0.5717	0.5629	0.5548	0.5473	0.5404	0.5340	0.5281	0.5225	0.5173
N1 = 31	0.5779	0.5681	0.5593	0.5511	0.5436	0.5366	0.5302	0.5242	0.5186	0.5133
N1 = 32	0.5745	0.5648	0.5558	0.5476	0.5401	0.5331	0.5266	0.5205	0.5149	0.5096
N1 = 33	0.5714	0.5616	0.5526	0.5443	0.5367	0.5297	0.5231	0.5170	0.5113	0.5060
N1 = 34	0.5684	0.5585	0.5495	0.5412	0.5336	0.5265	0.5199	0.5137	0.5080	0.5027
N1 = 35	0.5656	0.5557	0.5466	0.5383	0.5306	0.5234	0.5168	0.5106	0.5049	0.4995
N1 = 36	0.5629	0.5530	0.5438	0.5354	0.5277	0.5205	0.5139	0.5077	0.5019	0.4964
N1 = 37	0.5604	0.5504	0.5412	0.5328	0.5250	0.5178	0.5111	0.5048	0.4990	0.4936
N1 = 38	0.5580	0.5479	0.5387	0.5302	0.5224	0.5152	0.5084	0.5022	0.4963	0.4908
N1 = 39	0.5557	0.5456	0.5363	0.5278	0.5199	0.5127	0.5059	0.4996	0.4937	0.4882
N1 = 40	0.5535	0.5433	0.5340	0.5255	0.5176	0.5103	0.5035	0.4972	0.4912	0.4857
N1 = 41	0.5514	0.5412	0.5319	0.5233	0.5153	0.5080	0.5012	0.4948	0.4889	0.4833
N1 = 42	0.5494	0.5391	0.5298	0.5212	0.5132	0.5058	0.4990	0.4926	0.4866	0.4810
N1 = 43	0.5474	0.5372	0.5278	0.5191	0.5111	0.5037	0.4969	0.4904	0.4844	0.4788
N1 = 44	0.5456	0.5353	0.5259	0.5172	0.5092	0.5017	0.4948	0.4884	0.4824	0.4767
N1 = 45	0.5438	0.5335	0.5240	0.5153	0.5073	0.4998	0.4929	0.4864	0.4804	0.4747
N1 = 46	0.5421	0.5318	0.5223	0.5136	0.5055	0.4980	0.4910	0.4845	0.4784	0.4728
N1 = 47	0.5405	0.5301	0.5206	0.5118	0.5037	0.4962	0.4892	0.4827	0.4766	0.4709

Appendix 7: Percentile table.

This table was compiled from the relevant information Snodgrass (1977) page 411.

z	A(z,+)	z	A(z,+)	z	A(z,+)	z	A(z,+)
0,20	0,5793	0,40	0,6554	0,60	0,7257	0,80	0,7881
0,21	0,5832	0,41	0,6591	0,61	0,7291	0,81	0,7910
0,22	0,5871	0,42	0,6628	0,62	0,7324	0,82	0,7939
0,23	0,5910	0,43	0,6664	0,63	0,7357	0,83	0,7967
0,24	0,5948	0,44	0,6700	0,64	0,7389	0,84	0,7995
0,25	0,5987	0,45	0,6736	0,65	0,7422	0,85	0,8023
0,26	0,6026	0,46	0,6772	0,66	0,7454	0,86	0,8051
0,27	0,6064	0,47	0,6808	0,67	0,7486	0,87	0,8078
0,28	0,6103	0,48	0,6844	0,68	0,7517	0,88	0,8106
0,29	0,6141	0,49	0,6879	0,69	0,7549	0,89	0,8133
0,30	0,6179	0,50	0,6915	0,70	0,7580	0,90	0,8159
0,31	0,6217	0,51	0,6950	0,71	0,7611	0,91	0,8186
0,32	0,6255	0,52	0,6985	0,72	0,7642	0,92	0,8212
0,33	0,6293	0,53	0,7019	0,73	0,7673	0,93	0,8238
0,34	0,6331	0,54	0,7054	0,74	0,7704	0,94	0,8264
0,35	0,6368	0,55	0,7088	0,75	0,7734	0,95	0,8289
0,36	0,6406	0,56	0,7123	0,76	0,7764	0,96	0,8315
0,37	0,6443	0,57	0,7157	0,77	0,7794	0,97	0,8340
0,38	0,6480	0,58	0,7190	0,78	0,7823	0,98	0,8365
0,39	0,6517	0,59	0,7224	0,79	0,7852	0,99	0,8389
1,00	0,8413	1,20	0,8849	1,40	0,9192	1,60	0,9452
1,01	0,8438	1,21	0,8869	1,41	0,9207	1,61	0,9463
1,02	0,8461	1,22	0,8888	1,42	0,9222	1,62	0,9474
1,03	0,8485	1,23	0,8907	1,43	0,9236	1,63	0,9484
1,04	0,8508	1,24	0,8925	1,44	0,9251	1,64	0,9495
1,05	0,8531	1,25	0,8944	1,45	0,9265	1,65	0,9505
1,06	0,8554	1,26	0,8962	1,46	0,9279	1,66	0,9515
1,07	0,8577	1,27	0,8980	1,47	0,9292	1,67	0,9525
1,08	0,8599	1,28	0,8997	1,48	0,9306	1,68	0,9535
1,09	0,8621	1,29	0,9015	1,49	0,9319	1,69	0,9545
1,10	0,8643	1,30	0,9032	1,50	0,9332	1,70	0,9554
1,11	0,8664	1,31	0,9049	1,51	0,9345	1,71	0,9564
1,12	0,8686	1,32	0,9066	1,52	0,9357	1,72	0,9573
1,13	0,8708	1,33	0,9082	1,53	0,9370	1,73	0,9582
1,14	0,8729	1,34	0,9099	1,54	0,9382	1,74	0,9591
1,15	0,8749	1,35	0,9115	1,55	0,9394	1,75	0,9599
1,16	0,8770	1,36	0,9131	1,56	0,9406	1,76	0,9608
1,17	0,8790	1,37	0,9147	1,57	0,9418	1,77	0,9616
1,18	0,8810	1,38	0,9162	1,58	0,9429	1,78	0,9625
1,18	0,8830	1,39	0,9177	1,59	0,9441	1,79	0,9633

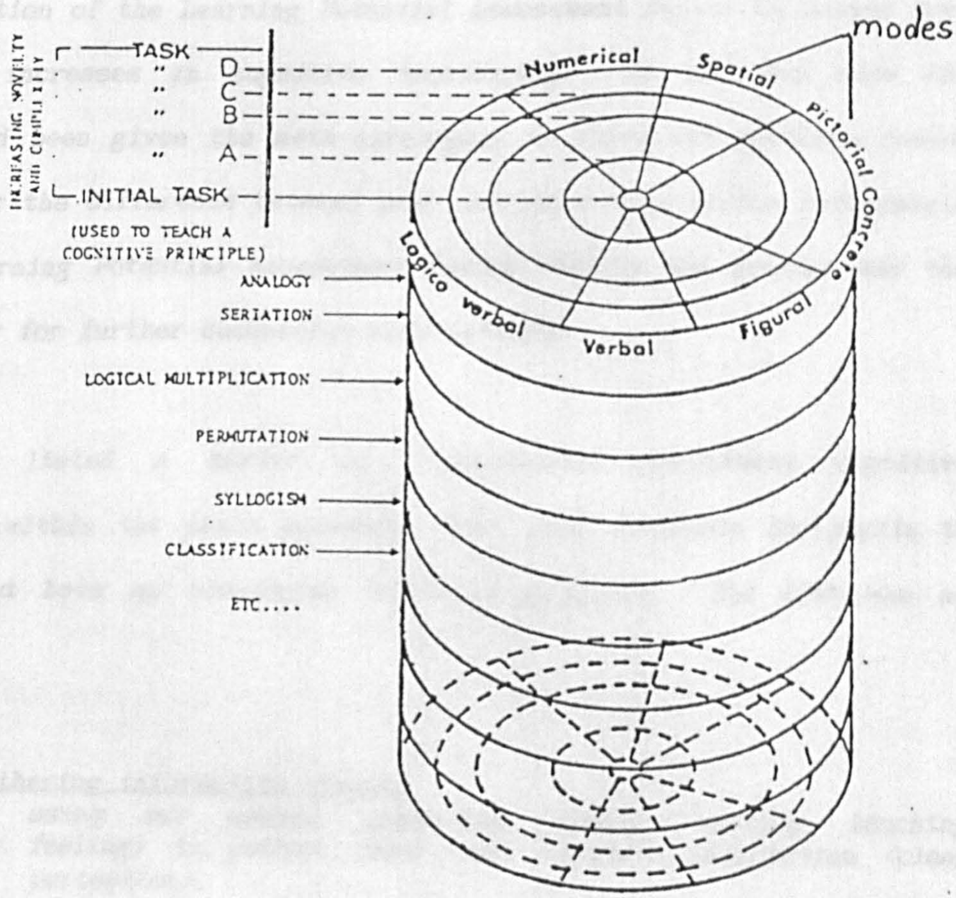
Appendix 8: Feuerstein's Learning Potential Assessment Device.

In applying the Learning Potential Assessment Device Feuerstein envisaged a cognitive map of seven parameters, Feuerstein et. al. (1980);

1) *Content (i.e. the subject matter with which the mental act deals),*
2) *Modality (i.e. the language in which the task is presented and elaborated, and the response expressed e.g. verbal, figural, numerical, symbolic, etc. singly or in combination),*
3) *Phase (i.e. input, elaboration or output),*
4) *Operations (i.e. mental activity such as categorization, seriation, logic, multiplication etc.),*
5) *Level of abstraction (i.e. distance of the mental content from the concrete object or event it represents),*
6) *Level of complexity (i.e. number of units of information and their scope as well as the degree of novelty and its weight relative to the familiar),*
7) *Level of efficiency (i.e. the speed and accuracy with which the act is performed).*

Items 2 and 4 are related as illustrated in Diagram appendix 8-1.

DIAGRAM APPENDIX 8-1: INTERACTION BETWEEN ITEMS 2, 4 & 6 OF FEUERSTEIN'S LEARNING POTENTIAL ASSESSMENT DEVICE FEUERSTEIN et al. (1980).



The modalities of a task were roughly represented by test of mental ability and by the segments in the diagram above. These could be increasingly complex represented by the successive rings. The operations involved were represented by the vertical sections of the cylinder. Thus it is possible to describe a task of a given modality in terms of complexity and the operation in which it could be a part. For example numerical problems can be described by complexity and whether the task involves seriation or categorization etc. (diagram appendix 8-1)or; seriation in terms of figural modality and complexity. Feuerstein's parameter 3 phase, was used as a framework within which the tester interpreted the child's responses, and the tester's interventions whilst administering the Learning Potential Assessment Device. Beasley (1984) measured changes on these cognitive functions observed during administration of the Learning Potential Assessment Device to assess pre-post-test increases in cognitive functioning. In addition once the subject had been given the meta-strategies to solve the problems posed, the greater the difference between pre- and post-intervention performance during Learning Potential Assessment Device testing the greater was the possibility for further successful modifiability.

Feuerstein listed a number of 'instrumental enrichment cognitive functions' within the phase parameter that were desirable for pupils to develop and have as strategies to solve problems. The list was as follows;

I) Gathering information (input)

1) *using our senses (listening, seeing, tasting, touching feeling) to gather, clear, and complete information (clear perception),*

2) *using a system or plan so that we do not skip or miss something important or repeat ourselves (systematic exploration),*
3) *giving the thing we gather through our senses and our experience a name so that we can remember it more clearly and talk about it (labelling),*
4) *describing things and events in terms of where they occur (spatial referents),*
5) *describing things and events in terms of when they occur (temporal referents),*
6) *deciding on the characteristics of a thing or event that always stay the same even when changes take place (conservation, consistency and object permanence),*
7) *being precise when it matters (need for precision),*
8) *organizing the information we gather, considering more than one thing at a time (using several sources of information):*

<u>II Using the information we have gathered (elaboration).</u>

1) *defining what the problem is, what we were being asked to do, and what we must figure out (analysing disequilibrium),*
2) *using only that part of the information we have gathered that is relevant, that is, that applies to the problem and ignores the rest (relevance),*
3) *comparing objects and experiences to others to see what is similar and what is different (comparative behaviour),*
4) *remembering and keeping in mind the various pieces of information we need (broadening our mental field),*
5) *organizing, ordering, counting and extracting main ideas in order to summarize our experiences and our knowledge (summative behaviour),*
6) *looking for the relationship by which separate objects, events, and experiences can be tied together (projecting relationships),*
7) *using logic to prove things and to defend your opinion (logical evidence),*
8) *having a good picture in our mind of what we are looking for, or what we must do (interiorization),*
9) *thinking about different possibilities of figuring out what would happen if you were to choose one or another (hypothetical thinking),*
10) *thinking about how to test which possibilities are better (test hypothesis),*
11) *making a plan that will include the steps we need to take to reach our goal (planning behaviour),*
12) *finding the class or set to which the new object of experience belongs (categorization);*

<u>III) Expressing the solution to a problem (output)</u>

1) *being clear and precise in your language to be sure that there is no question as to what your answer is, put yourself into the 'shoes' of the listener to be sure that your answer will be understood (overcoming egocentric communication),*
2) *if you can't answer a question for some reason, even though you 'know' the answer, don't fret or panic, leave the question for a little while and then, when you return to it, use a strategy to help you find the answer (overcoming blocking),*

3) *think things through before you answer instead of immediately trying to answer and making a mistake, and then trying again (overcoming trial and error),*
4) *using the best words we know to explain what we are doing or thinking to someone else,*
5) *carrying an exact picture of an object in your mind to another placed for comparison without losing or changing some detail (visual transport),*
6) *giving precise and complete answers,*
7) *take a minute to think about what you are going to say before you say it rather than jumping ahead with an answer that is not well though out.*

References

ARCHENHOLD et al. (1979) Cognitive developmental research in science and mathematics: *International Seminar proceedings University of Leeds for Science Education.*

ASSOCIATION FOR SCIENCE EDUCATION (1981), Education Through Science, *The School Science Review,* vol.63, no.222, pp.5-38.

AUSUBEL, D.P. (1968) *Educational Psychology: a cognitive view.* New York, Holt, Rinehart & Winston.

BEASLEY, F.P. (1984) *An evaluation of Feuerstein's model for the remediation of adolescents' cognitive deficits,* PhD London University.

BREDDERMAN,T.A. (1973) The effect of training on the development for the ability to control variables, *Journal of Research in Science Teaching,* 10(3), pp.189-200.

BRUNER,J.(1966) *Toward a Theory of Instruction* (Harvard University Press).

CANTU-SALINAS, L.L. (1978) Concrete-Formal Piagetian stages, Field-dependent Field-independent cognitive style, and science concept development, *Dissertation abstracts International,* Jan vol. 38(7-A).

CASE, R. (1974) Structures and strictures; some fundamental limitations on the course of cognitive growth, *Cognitive Psychology,* 6, pp.544-573.

DANNER, F.W. & DAY, M.C. (1977) Eliciting Formal Operations, *Child Development,* 48, pp.1600-1606.

DEPARTMENT OF EDUCATION AND SCIENCE (DES) (1981) *The School curriculum,* Her Majesties Stationary Office.

DEPARTMENT OF EDUCATION AND SCIENCE (DES) (1982) *Science Education in Schools,* Her Majesties Stationary Office.

DEPARTMENT OF EDUCATION AND SCIENCE (DES) (1983) *Curriculum 11-16: Towards a statement of entitlement,* Her Majesties Stationary Office.

DEPARTMENT OF EDUCATION AND SCIENCE (DES), (1984) *Assessment of performance unit (APU) (1984), Science at 11,* Her Majesties Stationary Office.

DEPARTMENT OF EDUCATION AND SCIENCE (DES) (1985a) *The Curriculum from 5-16,* Her Majesties Stationary Office.

DEPARTMENT OF EDUCATION AND SCIENCE (DES) (1985b) *Science 5-13: A statment of policy,* Her Majesties Stationary Office.

DEPARTMENT OF EDUCATION AND SCIENCE (DES) (1986) Assessment of performance unit (APU), *Planning science investigations at 11,* Her Majesties Stationary Office.

ENNEVER, L. & HARLEN, W. (1972), *With Objectives in Mind Guide to Science 5-13,* London, Macdonald Educational.

ELKIND, D. & SCOTT, L. (1962), Studies in Perceptual Development: I. The Decentering of Perception, *Child Development,* No.33, pp.619-630.

FEUERSTEIN, R. et al. (1980) *Instrumental enrichment,* University Park Press Baltimore.

FEUERSTEIN, R. & RAND, Y. (1974) *Mediated learning experience: and outline of the proximal etiology for differential development of cognitive function,* International Understanding, 9/10:7-37.

FLAVELL, J.H. (1963) *The developmental psychology of Jean Piaget,* New York D. Van Nostrand.

FLEXER, K. & ROBERG, J.J. (1980) *IQ,* Field dependence-independence, and the Development of Formal Operational Thought, *The Journal of General Psychology,* No.103, pp.191-201.

GAGNé, R.M. (1967), *Science: A Process Approach: purposes, accomplishments, expectations,* Washington, American Association for the Advancement of Science (AAAS Miscellaneous Publication 67-12).

GOODENOUGH, D.R. & KARP S.A. (1961) Field-independence and Intellectual Functioning, *Journal of Reaseach in Science Teaching,* Vol. 62, No.2, pp.241-246.

GUILFORD, J.P. (1973 Edition) *Fundamental Statistics in Psychology and Education,* McGraw-Hill, Inc.

HEAD, J. (1982) What Can Psychology Contribute to Science Education, *School Science Review,* Vol.63, No.225, pp.631-642.

HER MAJESTIES INSPECTORATE (1978), *Aspects of secondary education,* Her Majesties Stationary Office.

HORNE J.L. & CATELL, R.D. (1966) Refinement and test of the theory of fluid and crystallized general intelligence, *Journal of Educational Psychology,* No.57, pp.253-270.

HURONYMUS, LINDQUIST & FRANCE (1975) *Richmond Test of basic skills,* Windsor, National Foundation for Educational Research.

HYDE, J.S. (1981) How large are cognitive differences, *American Psychologist,* Vol.36, No.8, pp.892-901.

INNER LONDON EDUCATION AUTHORITY (ILEA) (1979), *Insight into Science,* ILEA.

INHELDER, B & PIAGET, J. (1978) *The Growth of Logical Thinking: from childhood to adolescence,* (New York, Basic Books).

JACKSON, S. (1963) *The Growth of Logical Thinking in Normal and Subnormal Children,* Summaries of researches in degree theses, Manchester University.

KEATING, D.P. (1975) Precocious cognitive development at the level of Formal Operations, *Child Development,* Vol.46, pp.276-280.

KUHN, D. & BRANNOCK, J. (1977) Development of the isolation of variables scheme in experimental and 'natural experiment' contexts, *Developmental Psychology,* 13, pp.9-14.

LAWSON, A.E. (1976) Formal operations and field independence in a heterogeneous sample, *Perceptual and Motor Skills,* 42, pp. 981-982.

LAWSON, A.E., BLAKE, A.J.D. & NORLAND, F.H. (1975) Training effects and generalization of the ability to control variables in high school biology students, *Science Education,* 59(3), pp.387-396.

LAWSON A.E. & RENNER, J.W. (1975) Relationships of Science Subject Matter and Developmental Levels of Learners, Journal of Research in Science Teaching, Vol.12, No.4, pp.347-358.

LAWSON, A.E. & WOLLMAN, W.T. (1976) Encouraging the transition from concrete to formal cognitive functioning: an experiment, *Journal of Research in Science Teaching,* 13(5), pp.413-430.

LIVINE, D.I. & LINN, M.C. (1977) Scientific reasoning ability in adolescence: theoretical viewpoints and educational implications. *Journal of Research in Science Teaching,* 14(4), pp.371-384.

LINN, M.C. (1978) Influence of cognitive style and traing on tasks requiing the separation of variables schema. *Child Development,* 49, pp.874-877.

LINN, M.C. (1980) Teaching students to control variables: some investigations using free choice experiments, IN MODGIL, S. & MODGIL, C. eds. *Towards a theory of psychological development,* Windsor, National Foundation for Educational Research, (1980), pp.673-698.

LINN, M.C. & KYLLONEN, P. (1981) The field dependence-independence contruct: some, one, or none, *Journal of Educational Psychology,* 73(2), pp.261-273.

LINN, M.C. & SWINEY, J.F. (1981) Individual differences in formal thought: role expectaions and attitudes, *Journal of Educational Psychology,* Vol.73, No.2, pp. 274-286.

LINN, M.C. & THEIR, H.D. (1975) The effect of experimental science on development of logical thinking in children, *Journal of Research in Science Teaching,* Vol.12, No.1, pp.49-62.

LOVELL, K. (1979) Some aspects of the work of Piaget in perspective, IN FLOYD, A. ed., *Cognitive development in the school years,* Croom Helm / The Open University Press, pp.13-28, 32-33.

LOVELL, K. & SHAYER, M. (1978) The impact of the work of Piaget on science curriculum development, *Knowledge and Development,* Vol.2, pp.93-138.

LUNZER, E.A. (1978) Formal reasoning a reappraisal, IN PRESSEISEN, GOLDSTEIN & APPEL, (Eds) *Topics in Cognitive Development, Vol 2: Language and operational thought, New York, Plenum Press.*

MACNEMAR (1962) Psychological statistics, New York, Wiley.

MILLINGTON, V. (1985) *Word Teaser,* Longman.

MODGIL, S. & MODGIL, C. (1976) *Piagetian Research: Compilation and Commentary,* Windsor, National Foundation for Educational Research.

MODGIL, S. & MODGIL, C. (eds.) (1982) *Jean Piaget: Consensus and Controversy,* London Holt, Rinehart and Winston, pp.351-363.

MORELL, J.A. (1976) Age, sex training and the measurement of field dependence, *Journal of Experimental Child Psychology,* 22, pp.100-112.

NEBELKOPF, E.B. & DREYER, A.S. (1970) Perceptual structuring: cognitive style differences in perception of ambiguous stimuli, *Perceptual and Motor Skills,* No. 30, pp.635-639.

NEIMARK,E.D. 1975a) Intellectual development during adolescence, IN HOROWITZ (ed.) *review of Child Development Research,* University of Chicago Press Vol.4, pp.541-594.

NEIMARK, E.D. (1975b) Longitudinal development of Formal Operational thought, *Genetic Psychology Monographs,* No.91, pp.171-225.

NEIMARK, E.D. (1979) The Current status of Formal Operational research, *Human Development,* No.22, pp.60-67.

NEIMARK, E.D. (1981) Confounding with cognitive style factors; an artefact explanation for the apparent nonuniversal incidence of formal operations, IN: SEIGEL,I., BRODINSKY,D. & GOLINKOFF R. (Eds) *Piagetian Theory and Research: new directions and applications* (Hillsdale N.J., Erlbaum).

NATIONAL FEDERATION FOR EDUCATIONAL RESEARCH (1979), *Science Reasoning Task II,* Windsor, National Federation for Educational Research.

OLTMAN, RASKIN & WITKIN (1971) *Group Embedded Figures Test,* Palo Alto: Consulting Psychologists Press.

PIAGET, J. (1964) Cognitive development in children: Development and Learning, *Journal of Research in Science Teaching,* 2, pp.176-186.

PEEL, C.A. (1976) The thinking and education of the adolescent, IN: VARMA & WILLIAMS (Eds) *Piaget's Psychology and Education,* chap. 14, Hodder & Stoughton, London.

ROSENTHAL, D.A. (1979) Aquisition of formal operations: the effects of two training procedures, *Journal of Genetic Psychology,* No.134, pp.125-140.

ROSENTHAL, R. (1978) Combining results of independent studies, *Psychological Bulletin,* Vol.85, No.1, pp.185-193.

SAARNI, C.I. (1973) Piagetian operations and field independence as factors in children's problem-solving performance, *Child Development,* 44, pp.338-345.

SAYER, S. & BALL, D. (1975) Piagetian cognitive development and achievement in science, *Journal of Research in Science Teaching,* No.12, pp.165-174.

SATTERLEY, D.J. (1979) Covariation of cognitive styles, intelligence and achievement, *British Journal of Educational Psychology,* 49, pp.179-181.

SELLY, N.J. (1981) Draft syllabus for teaching scientific thinking, *School History and Philosophy of Science Project;* Kingston on Thames, Kingston Polytechnic.

SHAYER, M. (1972) Conceptual demands in the Nuffield O-level physics course, *School Science Review,* Vol.54, No.186, pp.26-34.

SHAYER, M. (1974) Conceptual demands in the Nuffield O-level biology course, *School Science Review,* Vol.56, No.195, pp.381-388.

SHAYER, M. (1978a) Nuffield Combined Science: do the pupils understand it?, *School Science Review,* Vol.60, No.211, pp.210-224.

SHAYER, M, (1978b) The analysis of science curricula for Piagetian demand, *Studies in Science Education,* Vol.5, pp.115-130.

SHAYER, M, (1979) Has Piaget's construct of formal operational thinking any utility, *Brt. J. educ. Psychol.,* 49, pp.265-276.

SHAYER, M. (1980) Piaget and science education, IN MODGIL, S. & MODGIL, C. (eds.), *Towards a theory of psychological development,* Windsor, National Foundation for Educational Research.

SHAYER, M. & ADEY, P. (1981) *Towards a Science of Science Teaching* (London, Heinemann Educational).

SHAYER, M. & BEASLEY, F.P. (1987) Does Instrumental Enrichment Work?, *British Educational Research Journal* Vol.13, No.2, pp.101-119.

SHAYER, M. & WYLAM, H. (1978) The distribution of Piagetian stages of thinking in middle and secondary school children. II-14- to 16- year olds and sex differences. *Br. J. educ. Psychol.,* 48, pp.62-70.

SHAYER, M. & WYLAM, H. (1984) Science as a context for cognitive acceleration: a study and a proposal. Unpublished manuscript.

SEIGLER, R.S., LEIBERT, D.E. & LEIBERT, R.M. (1973) Inhelder and Piaget's pendulum problem, *Developmental Psychology,* 9(1), pp.97-101.

SMITH, M.L. & GLASS, G.V. (1977) Meta-analysis of psychotherapy outcomes studies, *American Psychologist, Vol.32,* pp.752-760.

SMITH, M.L. & GLASS, G.V. (1981) *Meta-analysis in social research,* Sage publications, Beverly Hills.

SNODGRASS, J.G. (1977) *The numbers game,* Oxford University Press.

SNOW, R.C., LOHMAN, D.F., MARCHALEK, B. YALOW, E. & WEBB, N. (1977) *Correlational analyses of reference aptitude constructs* (Tech. Rep. No. 5, Aptitude Research Project), Palo Alto, Calif.: Stanford University, School of Education.

SOMERVILLE, S.C. (1974) The pendulum problem: patterns of performance defining developmental stages, *Brit. J. Ed. Psych.* 44, pp.266-287.

STABLER, J.P. (1983) The relationship of the Field-dependent and Field-independent dimension of cognitive style to the display of formal operations in secondary school students, *Dissertation Abstracts International,* Vol.43, No.08, 2624-A.

STONE, C.A. & DAY, M.C. (1980) Competence and performance models and the characterization of formal operational skills, *Human Development,* 23, pp.323-353.

THE ROYAL SOCIETY (1982) *Science education: 11-18 in England and Wales,* The Royal Society, London.

THORNDIKE, R.L. & HAGEN, E. (1973) *Cognitive Abilities Test,* Windsor, National Foundation for Educational Research.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO) (1980) *Children's Devlopment,* UNESCO Handbook for Science Teachers, Unesco/London, Heinemann, pp.35-44.

VERNON, R.E. (1972) The distinctiveness of field independence, *Journal of Personality,* 40(3), pp.366-391.

WASON, P.C. & JOHNSON-LAIRD, P.N. (1972) *Psychology and Reasoning: Structure and Content,* London, Batsford.

WELLS, J. (1978) Some aspects of thinking in science, *Educational Research,* 24(17) pp.212-224.

WITKIN, H.A. (1962) Analytical functioning in perception, IN WITKIN, DYK, FATERSON, GODDENOUGH & KARP, *Psychological differentiation,* John Wiley.

WITKIN, H.A., GOODENOUGH, D.R. & KARP, S.A. (1967) Stability of cognitive style from childhood to young adulthood, *Journal of Personality and Social Psychology,* Vol. 17, No.3, pp.291-300.

WITKIN, H.A., MOORE, C.A., GOODENOUGH, D.R. & COX, P.W. (1977) Field-dependent and field-independent cognitive styles and their educational implications, *Review of Educational Research,* 47(1), pp.1-64.1