THE ACQUISITION OF FORMAL SCIENTIFIC REASONING BY PHYSICAL SCIENCE PUPILS IN STANDARDS EIGHT AND NINE

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ABSTRACT

The experimental training study was aimed at inducing combinatorial reasoning in adolescents. The training was Piagetian in nature but functioned simultaneously as an operationally defined Ausubelian advance organizer for novel learning material in chemistry.

The sample consisted of 161 pupils from an English-speaking co-educational high school in Johannesburg. The study employed a pretest-posttest control group design. The pretest consisted of Piaget's first chemical experiment. A technical procedure for trouble-free administration of this task is described. A detailed analysis of the structure of the task is also presented.

Training presented the conceptual framework, embodying, *inter alia,* a systematic approach, and three analogous problems. Pupils were trained individually. Criterion tasks consisted of the pretest in disguised form and a combinatorial problem involving switches which controlled an electric train set. The experimental group obtained significantly higher scores than the control group on both tasks. Prior to training, observed developmental levels of the experimental group were 24% concrete, 41% transitional, 24% early formal and 11% late formal. After training, these levels had improved to 1% concrete, 14% transitional, 80% early formal and 5% late formal. Training was detrimental to most late formal subjects.

Specific transfer was satisfactory since criterion tasks differed from the training task. A delayed test on the train evaluation task, three weeks after reinforcement of training, showed no significant difference from the immediate test.

The intrinsic effects of age, IQ and sex on the criterion tasks were not usually significant but older subjects of higher IQ tended to achieve better. However, higher IQ Standard Nine boys derived less benefit from training than other subjects.

Pupils received instruction on rates of chemical reactions. The experimental subjects performed significantly better in generating the subsumer consisting of the concept underlying the topic. They also tended to achieve better on the recall of factual knowledge pertaining to this topic, reaching significance for Standard Nine boys. Older subjects of higher IQ tended to obtain higher scores but not significantly so for the sample in general. IQ, rather than training, contributed to performance on issues requiring insight into the subject-matter.

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University, nor has it been prepared under the aegis or with the assistance of any other body or organisation or person outside the University of the Witwatersrand, Johannesburg.

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____________ day of ____________________, 19__.

In Loving Memory of
Willem James Morgendaal
1941 – 1983

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Science is a discipline which investigates the natural world and science education is a discipline devoted to discovering how to lead students to investigate the natural world.

J.W. Renner (1982)

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NOTATION

1. Concepts and Quotations

The new convention of italics to represent concepts and literature quotations has been adopted, rather than the traditional system of inverted commas.

2. Ausubelian Terminology

The term, *advance organizer*, has been retained exactly as coined by Ausubel and has been spelled in the American manner.

3. Decimal Point

The notation adopted by the South African Metrication Board, namely, the comma, has been used for the decimal point.

CHAPTER 1

INTRODUCTION

1.1 Motivation for the Study

The ideas in this thesis germinated in the classroom and the author was motivated to carry out this study through her involvement in teaching physical science to pupils of senior secondary school level. Personal experience has served to highlight a wide range of problem areas influencing pupil achievement and interest in physical science. These areas include pupil characteristics such as motivation and intellectual capacity. The latter implicates the degree of possible mismatch between the demands of science courses and the level of cognitive development of the learners. Such problems are not indigenous to South Africa alone but are of international concern as will be discussed later. On the national level, the Scientific Advisory Council to the then Prime Minister requested the Human Sciences Research Council (HSRC) to conduct an investigation into the disquieting state of affairs in the teaching of natural science subjects at secondary level. The resulting series of reports identifies a lack of interest of pupils in these subjects. The authors claim that this is a direct result of extensive abstract-theoretical syllabuses and the inadequate training and qualifications of the teachers responsible for inculcating these subjects (HSRC, 1981; Swanepoel, 1981). They suggest that, in the likely revision of the physical science syllabus, consideration will have to be given to making it shorter, less abstract-theoretical and more relevant to industrial applications (Swanepoel, 1981, 1983). Adapted syllabuses which take cognisance of these proposals, are being implemented at the junior secondary level for the first time in 1984. Syllabus modification will gradually be extended to include the entire senior secondary level by 1987.

A revised syllabus may perform a significant alleviatory function but cannot be viewed as an independently sufficient measure to rectify the pressing situation in science education. Numerous important concepts in physical science are intrinsically abstract and formal* thought is required for understanding the critical attributes of these concepts. Many senior secondary pupils still function at the concrete* level on intellectual tasks in general. Although perceptual cues in the form of physical models can possibly be provided to help compensate for

*The terms *concrete* and *formal* refer to Piaget's definitions which are explained fully in Chapter 2.

reasoning or television, many educationalists hold that no teaching strategy will eliminate the difference in achievement between concrete and formal operational pupils. If the comprehension of physical science is to be improved, a major objective is to graduate students who think at the formal level and attention of educationalists should be directed towards the development of procedures that can be used to promote intellectual growth.

The focus of this investigation is the development of a strategy to foster achievement in physical science by pupils of a wide range of intellectual abilities. A particular aim of the research, therefore, is to see whether formal reasoning can be induced in the classroom situation by adopting a suitable teaching programme.

1.2 Theoretical Background

Developmental stages in formal thinking have been formulated by Piaget and, as will be discussed in the next chapter, have been the subject of a large body of literature. The two stages which are relevant to high school education are the stages of concrete and formal thought, each of which may be dichotomised into early and late substages. Assessment of the cognitive ability of an individual is generally instrument-dependent. A pupil who may exercise early formal behaviour on one intellectual task may function at a late concrete level on another task which differs in context or in content. This suggests the richness of the prior experience of an individual as a determinant of subsequent learning. It also raises questions such as the degree of internal coherence of the thinking strategies or operations which characterise a particular developmental level. It is obviously beyond the scope of a single thesis to be able to study in detail all these considerations. The objective of the present investigation is to study the acquisition of combinatorial reasoning (which Piaget designated as the distinctive operation marking the appearance of formal thought).

Combinatorial reasoning is indispensable for the solution of a wide range of problems as it allows the consideration of all possible combinations of variables. Flavell (1963) has defined combinatorial analysis as

> ... a systematic isolation of variables. Operationally, each variable or combination is tested until a solution(s) to each problem is uncovered.

This property of formal thought is demanded by many concepts which occur in school science syllabuses. (Two such examples are momentum and kinetic energy.) It was therefore felt that a step forward in teaching methodology could be achieved if it could be demonstrated that combinatorial reasoning could be induced in a group of pupils at an earlier age than would occur without intervention. This would afford a double advantage if the training programme in combinations operations could be structured in such a way as to be effective as an introduction to novel academic matter. In the proposed instructional sequence, the most general and inclusive ideas, namely, the training programme, would be presented first to provide conceptual anchorage, or, loosely, a frame of reference, for optimum absorption of subsequent learning material, namely, unfamiliar material from the physical science syllabus, which is more differentiated in terms of specificity and detail. This type of approach is known as progressive differentiation and is part of Ausubel's theory of meaningful learning which will be discussed in the next chapter.

The present work is concerned with formal reasoning in pupils in the 14-[illegible] age group. This is normally acquired, if at all, by natural maturation of the pupils and the major aim of the work is to investigate whether combinatorial formal reasoning can be induced and applied to novel academic matter at an earlier stage of development through (i) appropriate training programmes, and (ii) teaching procedures that are carefully structured both in selection and sequencing of content. It has been suggested in the literature on theoretical grounds that the theories of Piaget and Ausubel are not mutually exclusive but could be viewed as complementary guides for research. The complementarity of the approaches has not however been investigated experimentally and the present study pivots around the elements of this theme.

The approach in this study can, on the one hand, be classified as Piagetian in nature as the study is concerned with assessing and subsequently improving the operational capabilities of the pupils as interpreted in the context of Piagetian combinatorial tasks. The instrument by means of which the feasibility of inducing development is explored, consists of a training procedure in which the adolescents are instructed in problem-solving strategies. Emphasis has been placed on the overriding criteria of whether and to what extent training is retained and to what extent cognitive skills learned are transferable to unfamiliar instructional material.

Many criticisms have been levelled at work published by Piaget and his co-workers on the grounds of inadequacies in the execution of the investigations, in the reporting of the findings and in the interpretation in terms of the over-all theory. A secondary aim of this study therefore is to analyse critically by means of personal interviews the structure of Piaget's first chemical experiment and interpretation of the meaningfulness of success criteria.

The approach used in the present study can, on the other hand, also be viewed as Ausubelian in nature, i.e., the research hypothesis is that the training procedure, introduced prior to the material to be learned and presented at a higher level of generality, can facilitate the meaningful learning of subsequent instructional material. The literature search in the next chapter shows that an Ausubelian orientation does not exclude, nor even undermine, the selection and presentation of the content of instruction from a Piagetian viewpoint. Both theories would accept that the human organism strives to make sense of its environment i.e. the world in which we live. Making sense of a new phenomenon means *forming a conception which is intelligible, plausible and fruitful.* (Hewson, 1983). These three attributes can arise only in relation to a person's existing conceptions. The importance of existing knowledge in the learning of new experiences and new ideas forms the foundation of both Piagetian and Ausubelian models. This does not imply, however, that the two models are identical since they tend to differ in the meaning attached to the term, *knowledge*. As shown in the next chapter, the Piagetian interpretation of this term revolves around levels of cognitive competence while the Ausubelian interpretation focuses on the range of information stored in a person's mind.

Both theories regard knowledge as derived from experience, as will be discussed in the next chapter. The emphasis of both theoretical stances on the importance of prior knowledge to subsequent learning has determined the shape and sequence of steps in the thesis as a whole. As a point of departure for the investigation, the use of a pretest is thus demanded on theoretical grounds since pupils may have had different prior knowledge (as well as by the statistical requirements discussed in Chapter 3).

In summary, the present study attempts to raise the operational capabilities of the learner to match the logical demands of selected portions of the physical science curriculum while simultaneously employing the Ausubelian principle of progressive differentiation for the selection and sequencing of instructional material. The latter principle is used, not only for the material from the curriculum but also in shaping the relationship of this material to the training. Of particular significance, therefore, is that the Piagetian training procedure fulfils a dual purpose as it is also employed in the Ausubelian sense as a deliberate intervention to afford a global view to the learner of the concepts underlying the subsequent learning material from the science syllabus. The aim of the thesis, therefore, is to relate results from both theories when these theories are regarded as complementary in order to ascertain the implications for science instruction. It endeavours to suggest in what way both Piagetian and Ausubelian approaches can best be used in classroom situations to achieve optimum benefit for pupils of a wide ability spectrum. The research is intended to provide significant remedial data since the ability to manipulate variables is indispensable for mastery of high school physical science curricula.

1.3 Overview of Hypotheses

The thesis sought to answer two central questions

1. Is it possible to develop a procedure to promote intellectual growth? In particular, is it possible to induce formal thought in the form of combinatorial reasoning which is retained and can be transferred?

2. Is it possible that the above procedure, which meets Piagetian criteria, also meets the requirements of an Ausubelian appreach in the sense that it can facilitate the learning of novel academic material?

The design of such a project required the formation of hypotheses directed at the following issues :

(i) Prior to any intervention, were the experimental and control groups equivalent in combinatorial reasoning abilities?

(ii) After training, was the experimental group superior to the control group on appropriate tasks? Was superiority

- retained?
- transferable?

(iii) Prior to instruction, were the experimental and control groups equally unfamiliar with the selected academic material?

(iv) After teaching, was the experimental group superior to the control group

- in reproducing facts?
- in deeper conceptual insights?
- in thinking combinatorially?
- in thinking formally?

The first and third of the above groups of hypotheses related to the statistical requirements of the research design. The necessity for the testing of retention and transfer of the training, specified in the second group of hypotheses, arose from criteria for effective interventions aimed at the acceleration of intellectual development. Piaget and Ausubel both insisted that successful training must be lasting and also generalisable to other tasks requiring the same mental operations. One of the issues addressed by current research in education is the nature of the development of formal operations with respect to the order and degree of their intraindividual appearance. The thesis was centred on combinatorial reasoning but evaluation of the training should entail consideration of whether training in combinatorial skills fostered the development of other cognitive operations characteristic of formal thought, for example, compensations abilities. This facet of assessment was included in the fourth group of the above hypotheses.

One of the key aspects of Piagetian theory is maturation. Any investigation based on developmental theory ought to include extensive consideration of age effects. It would be desirable if training procedures could be shown to be effective for pupils at an early stage of senior high school. The science subject-matter covered in the Standard Eight year forms the foundation of the Standards Nine and Ten years in which the same work is examined in greater depth. It therefore seems reasonable to study the parameter of age in terms of division of the sample by school standard. The consideration of different categories of pupils also ought to yield useful information concerning the degree of success and general applicability of the training. In addition to age, therefore, the further independent variables of IQ and sex featured throughout the study. The literature suggests that, while achievement on Piagetian-type tasks is not always linked to IQ and sex, these variables are predictors of achievement in science learning. Research has shown that high IQ pupils usually outperform their lower IQ peers while boys often achieve better than girls. The subsidiary hypotheses in the thesis were therefore formulated to resolve the issues of whether the factors of age, IQ and sex gave rise to

- differential performance on Piagetian-type tasks by untrained subjects.
- differential achievement on academic material by untrained pupils.
- differential receptivity to training.

1.4 Overview of Methodology

The present work is essentially an experimental study and, in particular, it is aimed at the classroom situation. The subject of investigation is therefore interdisciplinary and, with this in mind, a highly formalised mode of presentation of the thesis has been deliberately avoided.

The study utilised a pretest-posttest control group design. The justifications for the research design are incorporated in the later and more comprehensive chapters. The experimental procedure was determined chiefly by the factors of theoretical stance and statistical requirements. Appropriate aspects of both Piagetian and Ausubelian theories, as already mentioned, were used to organise the investigation. Statistical methods were studied in some detail and it was decided that nonparametric techniques were the most valid for this kind of research study, although generally in the literature, nonparametric tests are not often used (Chapter 3).

The function of this introductory chapter is to provide an overview of the aims and content of the thesis, hence a summary of the experimental procedure follows. The summary is shown as a flow diagram in Figure 1.1.

1. The sample of 161 pupils was divided by age, IQ and sex into eight blocks. The experimental treatment was assigned at random to half the pupils in each block while the control treatment was assigned to the rest of the pupils in the block (Chapter 3).

2. All pupils in the sample were pretested individually using the first chemical experiment of Inhelder and Piaget (1958), which involves combinations of colourless chemical liquids. To accomplish this, at the outset it was necessary to

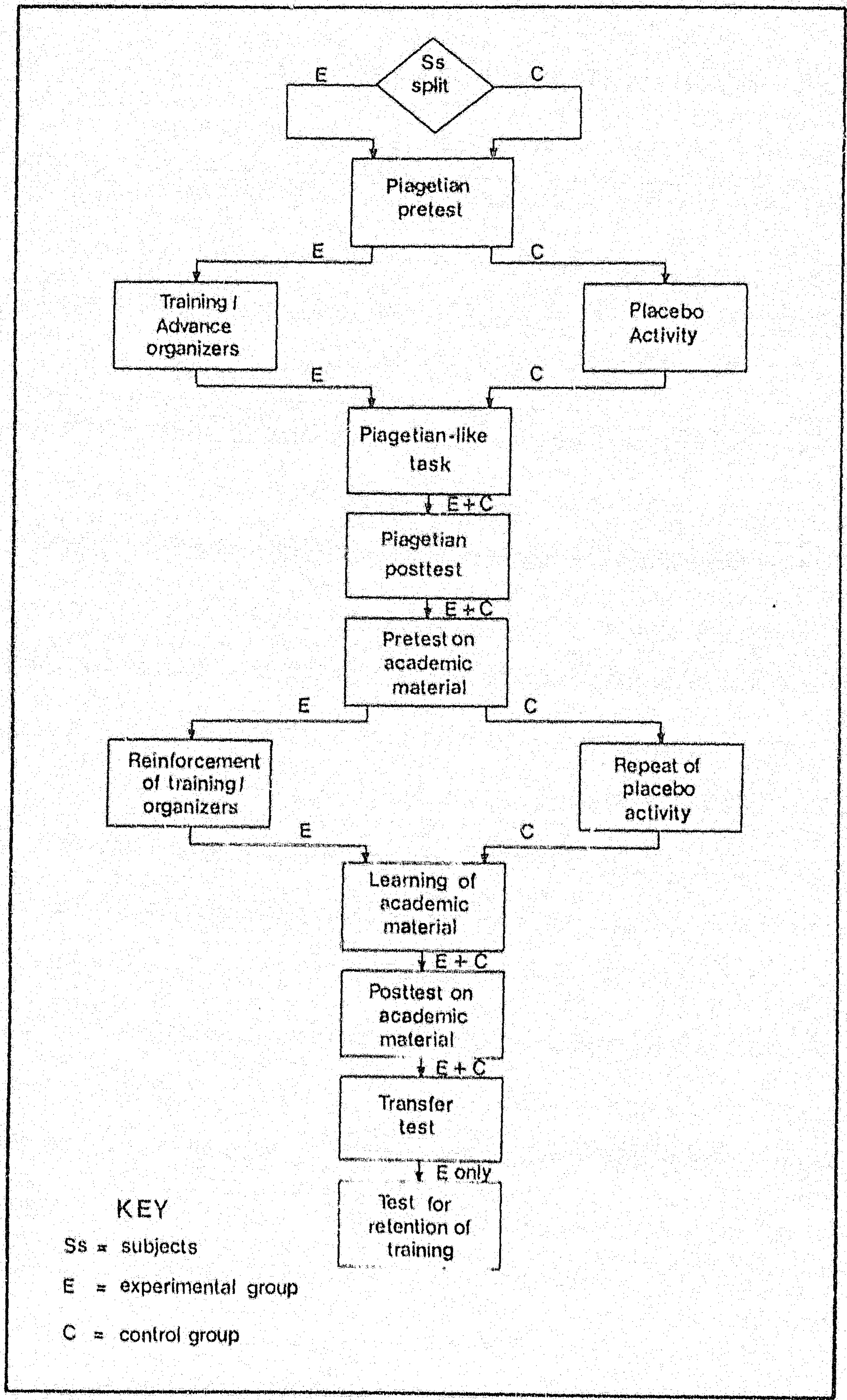

Figure 1.1 Flow Diagram Showing the Experimental Procedure

- develop a trouble-free procedure for administration of this task.
- analyse the structure of this task.

3. The experimental and control treatments diverged at this point.

   (a) The pupils in the experimental blocks were subjected individually to training in the design of factorial experiments. The training procedure was an adaptation of the method described by Siegler and Liebert (1975). The instructional strategy was characterised by exposition and elucidation of a systematic approach to combinatorial tasks as typified by a tree diagram in which factors and their levels could be represented schematically (Chapter 5).

   (b) The pupils in the control blocks were subjected individually to placebo treatment. The initial placebo activity required the disconnection and reassembly of the parts of a puzzle. Next, each subject was presented with written problems concerning an electric train, based on interactive patterns devised by Siegler and Atlas (1976). (Chapter 5).

4. The task designed to measure the effectiveness of training was then administered to all pupils. This task consisted of a modified version of the instrument invented by Siegler and Liebert (1975), analogous to Piaget's first chemical experiment (Chapter 6).

5. The posttest as a further measure of the effectiveness of training in the promotion of intellectual growth, consisted of the pretest in disguised form (Chapter 7).

6. Suitable instructional material involving factorial combinations which were logically analogous to Piaget's first chemical experiment, was compiled from various sources and from the author's personal experience. Prior to instruction, a pretest dealing with the selected topic of rate of chemical reactions, was administered to all the pupils (Chapter 8).

7. The experimental and control treatments diverged once more. Reinforcement of the training was given to subjects in the experimental blocks (Chapter 5).

8. The 161 pupils were divided into nine classes, each of which was given instruction on the rate of chemical reactions. The total duration of tuition was three-and-a-half hours per class (Chapter 9).

9. A posttest on rate of chemical reactions was then administered. The sections of the posttest dealt with

(i) factual knowledge,
(ii) application of factual knowledge to specific situations;
(iii) combinations of the variables in chemical data;
(iv) selection of reaction conditions for industrial or other purposes.

Portions of the posttest functioned simultaneously as a test of transfer of the training (Chapter 10). On the same occasion, a retention test on the training was also administered (Chapter 10).

CHAPTER 2

LITERATURE SURVEY

2.1 Paradigms of Learning

The prime objective of this investigation is the design, development and testing of an instructional strategy which will enhance achievement in physical science by pupils of a wide range of intellectual abilities. Before such empirical issues can be tackled, a description of theoretical issues pertaining to the psychology of learning and an analysis of cognitive factors underlying achievement in physical science are required.

This thesis is therefore initiated by a brief discussion of the different positions or paradigms adopted by educationalists. Paradigms, as defined by Gage (1963), consist of *models, patterns or schemata* which are useful ways of thinking. As Kuhn (1970) points out and Lakatos (1976) elaborates, advances in any discipline (including science education) arise from systematically employing a paradigm to guide research. The meaning of a paradigm in functional terms has been described by Posner *et al* (1982, p. 212) as the central commitments which usually organise scientific research. In any discipline, especially those which are young and vital, there should be competing paradigms (Lamb, 1976; Power, 1976). Since ultimately all paradigms are modified or discarded, the issue is not whether the paradigm is true but whether it is useful (Novak, 1979).

In research on science learning, a number of paradigms in the field of cognitive psychology has been developed, the three most established and hence the most used of these currently being reception learning theory (as represented by information-processing psychology), developmental learning theory and hierarchical learning theory (Berger, 1979; Lawson, 1979a; Jones and Russell, 1979; Novak, 1979). An emerging area of research in this field is constructivist psychology (Driver, 1981). All of these have provided a basis for subsequent experimental investigations.

2.2 Current Status of Eclectic Approaches

Until recently, each of these paradigms was carefully evaluated and studiously applied by its protagonists as the single viable model of learning, an antithesis of rival theories. There seemed to be no evidence of a dialectically-minded approach in which the theories were recognised as useful aspects of the same whole. For example, Novak has argued for years in *Science Education* that Piaget's theory of intellectual development as a theoretical basis for research in science education should be supplanted by Ausubel's theory of meaningful learning (Novak, 1974a, 1974b, 1975, 1976a, 1976b, 1977a). This attitude has been criticised by Herron (1978) who also cites references in which this position has actually been sharpened (Novak, 1976c, 1977b, 1977c, 1977d). Berger (1979), discussing considerations critical for achievement in paradigm-based research in science education, states :

> *... to argue for one or another paradigm may prevent science educators from realizing that all such paradigms may fit into a larger construct.*

It has lately been suggested that the theoretical bases of the different research traditions are not mutually exclusive in that they do not offer alternative interpretations of the same sets of observations but are addressed to different problems (Albert, 1979; Berger, 1979; Driver, 1981; Herron, 1978). Although the areas of research are directed to different issues, the balance between the theories and the contribution each has to make depends on certain epistemological assumptions made within the research and teaching communities. Regarding the implications for science education, each theory projects a significantly different view of the nature of science and hence its role in education (Driver, 1981). It is therefore inevitable that these theories have been attacked, totally or in part, by a number of investigators. It has been contended, for example, that Piaget's logical model is an inadequate explanatory theory for intellectual developmental levels (Wason and Johnson-Laird, 1972; Ennis, 1975), that the Piagetian approach is overly occupied with stage components (Kubli, 1979) and underestimates the role of prior knowledge in the determination of performance (Bady, 1978; Novak, 1977c). In addition to Piagetian researchers who have been critical of the Ausubelian position, particularly as espoused by Novak (see previous references), Strike and Posner (1976) consider Ausubel's concept of meaningful learning as lacking detail, leading to unnecessary vagueness and misinterpretation. The absence of concern with memorial processing mechanisms has been identified by Atkin (1977) and Van Kirk (1978) as a further shortcoming of Ausubel's theory. The current status of each of the two theories will be discussed later in this chapter with more comprehensive reference to the literature.

Only very few paradigms of learning (apart from Gagné's (1965, 1966) learning hierarchy) have been proposed as alternatives to the Piagetian and Ausubelian frameworks. Two promising theoretical models which exhibit the recent trend towards eclecticism and derive largely from the current philosophy of science, pivot around original elements but subsume the perspectives of Piaget and Ausubel to a greater (Stewart and Atkin, 1982) or lesser (Posner *et al*, 1982) degree. Stewart and Atkin, encouraged by the efforts of Case (1978) to subsume Piagetian research into an information-processing framework, have proposed a model which has as its focus an elaborated view of the structure and function of human memory. Posner *et al* (1982) view both inquiry and learning as a process of conceptual change and have put forward a general theory to describe and to explain the substantive dimensions of the strategy whereby the dominant, organising concepts of an individual are restructured, or fundamentally changed, from one set of concepts to another set, irreconcilable with the first.

Both these theories are novel in character and still in the developmental stage. They have thus not yet achieved a roundedness which might enable them to replace the paradigms of Piaget and Ausubel as a general basis for experimental research directed at the classroom situation. Despite weaknesses in the Piagetian and Ausubelian traditions, many of the basic tenets have been regarded as sound by the majority of workers and can be used as a basis for learning studies.

The Ausubelian and Piagetian approaches to learning may very likely be assessed on theoretical grounds as complementary guides to educational research. The complementarity of these theories has not hitherto been investigated empirically and this is the major object of the present research study. The basic tenets of the two theories will now be discussed within this frame of reference.

2.3 Reception Learning

2.3.1 Ausubelian Background

Reception learning is defined as that form of learning where the regularities to be learned and their concept labels are presented explicitly to the learner (Novak, 1979). The most widely held theory of reception learning is information-processing psychology which was proposed by Ausubel *et al* (1957) and expounded in 1967 (Ausubel, 1967). A modified version was later published (Ausubel *et al*, 1978) and the current status of the theory has been reviewed by Novak (1979). This reference made by the writer to the work of only Ausubel and his collaborators does not imply that no valuable research has been conducted in the domain of information-processing psychology by other workers, as considerable progress has been made in this field recently (see earlier references in section 2.2).

The Ausubelian framework derives from earlier cybernetic theories but presents a cognitive view of learning in contrast to the behaviourist tradition. The behaviouristic view regards intellectual development as the sum total of isolated learning experiences consisting of provoked encounters with a set of *external conditions* or predictable, controlled manipulations of the learning environment. This includes Gagné's cumulative learning model (1965, 1970, 1977) which identifies conditions similar to the hierarchical learning paradigm of Bruner *et al* (1967). Use of the behaviouristic model directs research towards finding rules, principles and strategies of concept attainment with environmental control an essential feature of the approach. The domain of intellectual skills learning is thus approached from an external point of view. The exact position of Ausubel in the behaviourist/cognitivist dichotomy is controversial (Albert, 1979; Driver, 1981; Novak, 1979; Strike, 1974), but, unlike the skill integrationists, Ausubel focuses on the nature and role of cognitive processes in learning, contending that the way in which knowledge is organised by the learner affects subsequent learning.

1.3.2 Theoretical Overview

A key term in Ausubelian theory is *structure*. The word *structure* comes from the Latin *struo* (I place, I join) and commonly denotes the mode of organisation or connection of constituent parts into a coherent whole. Ausubel has adopted this meaning of the word in the new context of the psychological arrangement of knowledge as well as the ability of this arrangement to accrete new knowledge. Cognitive structure in the Ausubelian sense, therefore, refers to *both the substantive content of an individual's structure of knowledge and its major organizational properties in a particular subject-matter field* [*or fields*]. (Ausubel, 1968, p. 127). Ausubel assumes that cognitive structure is exemplified by a hierarchically-ordered pyramid in which the most comprehensive and broadly explanatory ideas occupy a position at the apex of the pyramid. Progressively less inclusive, or more differentiated, subconcepts as well as specific informational data are then successively *subsumed*, namely, placed in a subordinate position which is, however, linked to the next higher step in the hierarchy.

The established relevant idea in cognitive structure, to which a new idea may be related, is called the *anchoring idea*. Ausubel hypothesises the principle of *assimilation* in which the potentially meaningful new idea is incorporated into cognitive structure in such a way that the idea, in fresh or modified form, emerges in linked relationship to the anchoring idea. The anchoring idea itself is also changed by interaction with the new idea. Ausubel then postulates that the modified new idea and the modified anchoring idea are linked co-members of a new composite ideational unit or complex. The assimilation process is claimed to account for the subsequent forgetting of ideas by the learner. Immediately after learning, the second or *obliterative* phase of assimilation commences. The recently learned idea spontaneously becomes less and less dissociable from the new ideational unit, until eventually it is no longer available as a separate entity and is said to be forgotten by the learner. The final phase of the assimilative process is the reduction of the ideational unit to only one of its components, specifically, to the anchoring idea (in its modified form as a result of the interaction). Ausubel maintains that these occurrences are inevitable and are due to *the erosive influence of the general reductionist trend in cognitive organization* (Ausubel, 1968, p. 93) which exists for reasons of economy and lessening intellectual burden.

2.3.3 Meaningful Learning

Ausubel distinguishes between rote and meaningful learning. According to his theory of learning, meaningful learning takes place during the internalisation process when symbolically expressed ideas are incorporated into some specifically relevant structure of already existing knowledge, as opposed to rote learning where tasks are relatable to cognitive structure only in an arbitrary, verbatim fashion which does not result in the acquisition of any meanings.

In reception learning, whether rote or meaningful, the entire content of what is to be learned is presented. The learning task does not involve any independent discovery on the part of the learner. This contrasts with learning as seen by developmental psychology. The latter kind of learning is known as discovery learning and is characterised by the fact that the learner must discover the principal content of what is to be learned. Discovery learning is therefore active, spontaneous and self-directed. However, meaningful reception learning is not a passive cognitive process but demands learner activity in which new meanings are effectively subsumed into existing ideational content in the cognitive structures.

> *The extent to which meaningful reception learning is active depends in part on the learner's need for integrati[illegible] meaning and on the rigorousness of his self-critical faculty.*
> (Ausubel, 1968, p. 88).

A clear distinction between the two independent learning dimensions of rote-meaningful and reception-discovery is one important contribution of Ausubel's learning psychology (Novak, 1979). Figure 2.1 schematises the rote-meaningful and reception-discovery continua (Novak, 1979). Hence, both reception and discovery learning can be either rote or meaningful depending on the conditions under which learning occurs (Ausubel, 1968, p. 24). Ausubel points out that intellectual functioning usually involves the acquisition of large bodies of subject matter through reception learning and the solution of the everyday problems of living through discovery learning (Ausubel, 1968, p. 23).

2.3.4 Theory of Instruction

The key issue in Ausubel's theory of instruction is the sequencing of material to achieve efficient induction into knowledge. The theory is founded on the traditional didactic principle of proceeding from the known to the unknown :

> *If I had to reduce all of educational psychology to just one principle, I would say this : The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.* (Ausubel, 1968).

Ausubelian theory and other paradigms of learning are drawn together in a common formulation on this point. The importance in the learning process of prior knowledge has been shown by Gagné (1965) and other workers, notably White (1974), who have stressed the hierarchical organisation of concepts, namely, that for the learning of any specific concept, there are subordinate concepts which are prerequisites. Their work has concentrated on the conditions controlling the acquisition of specific intellectual skills and does not provide information about the meaningful dimension in the learning of the skills, which is a focus of interest in Ausubel's theory (West and Kellett, 1981).

Jean Piaget (1964a),father of developmental psychology, places similar, but not equivalent, restrictions on the kind of teaching which will be of value in developing scientific concepts. The restrictions are not equivalent since the meaning given to *cognitive structure* by Piaget differs from the Ausubelian interpretation of the same term, as will be seen in a later section of this chapter. Nevertheless, in a certain sense, Piaget advocates instruction characterised by a point of departure which is known to the learner. Meaningful learning may involve only those intellectual skills which are familiar to the learner. Piaget argues, therefore, that any effective instruction must

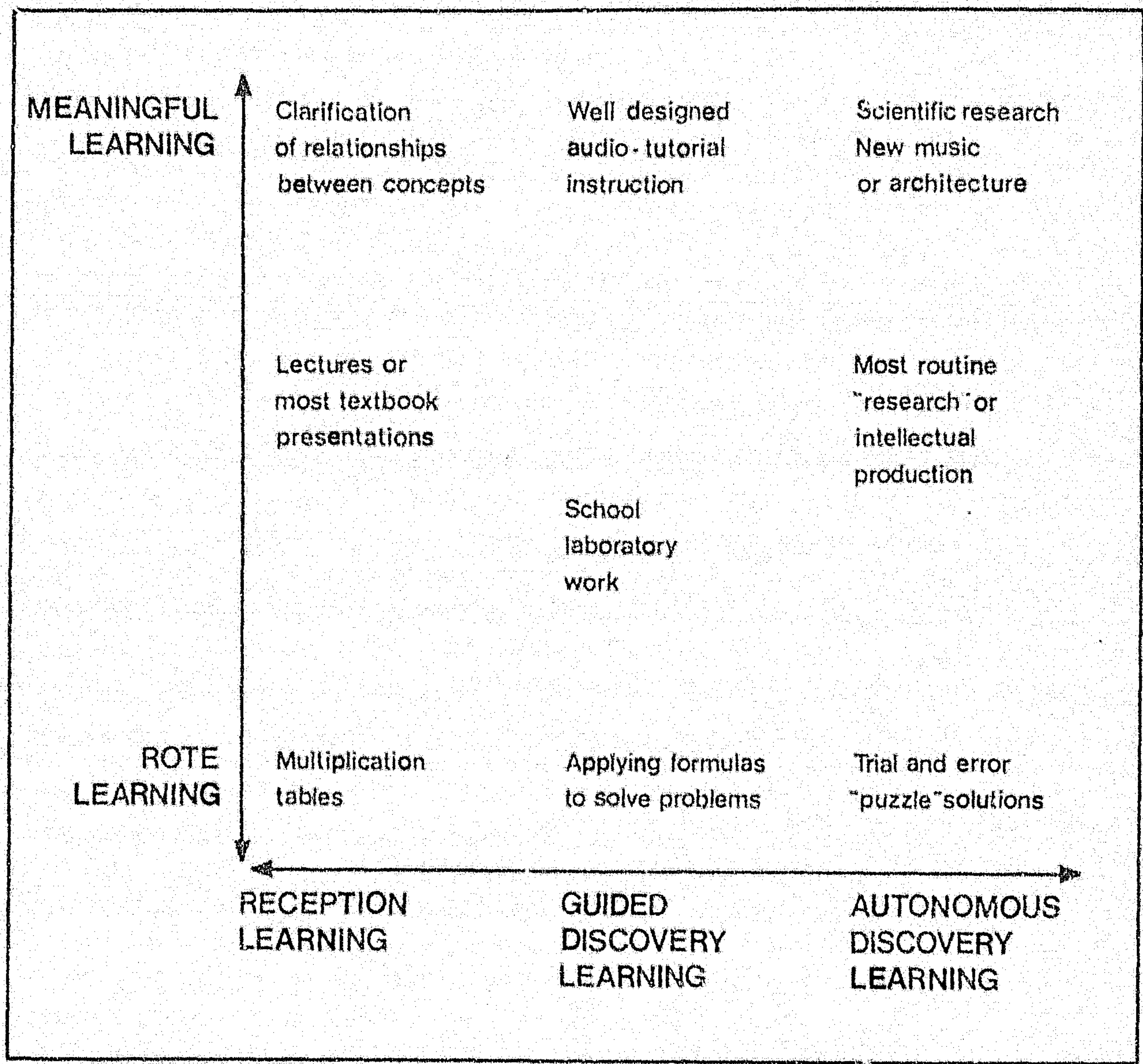

Figure 2.1 The Rote-Meaningful, Reception-Discovery Continua (Reproduced from Novak (1979))