Children's Understanding of Quantity:
The development of appreciation of conservation of quantity in educationally subnormal children

by

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ABSTRACT

The research was concerned with the development of understanding of invariant quantity in mentally handicapped children. In a series of investigations, 317 educationally subnormal schoolchildren aged 8 to 16 with IQs between 42 and 81 were pre-tested in Piaget-type situations for, variously, conservation of number, substance, length, distance, area, weight, and volume. Experimental groups of nonconserving children, matched to control groups of non-conservers, were given instruction on conservation and then post-tested some weeks later.

The five investigations, each of which is reported separately and in detail, provided answers to 6 central questions. First, it was found that it is possible to develop understanding of conservation in educationally subnormal children by instruction. Second, such understanding can be developed using teaching which includes a large amount of varied relevant experiences and explanations in concrete situations. Third, the understanding developed by instruction was shown to be generalised and durable. Fourth, a uniform sequence was found in the spontaneous development of conservation in educationally subnormal children: conservation of number before substance and length before weight before volume and area. Fifth, the particulars of the situation facing the child were shown to influence conceptual recognition of conservation of number, substance, area and volume and also perceptual recognition of continuing equality of length and area. Sixth, a child's response to teaching was found to be influenced by some interaction between his initial level of understanding and the fullness of the instruction given to him.

CHAPTER 1

INTRODUCTION

It was Piaget who first systematically studied the development of understanding of conservation of quantity. He revealed how normal children between the ages of about 6 and 11 gradually come to recognise that quantities remain invariant throughout irrelevant transformations. His main findings on the spontaneous development of conservation have been confirmed by subsequent studies by e.g. Elkind (1961, a & b)Lovell and Ogilvie (1960, 1961 a & b); and further studies have been carried out which have attempted to teach conservation.

Various authors have reviewed Piaget's work and that of other investigators concerned with the development of understanding of conservation. Reference can be made to Flavell (1963), Baldwin (1967), and Hunt (1961) for comprehensive consideration of Piaget's work and to Sigel & Hooper (1968), particularly, for a selection of important studies following Piaget. Lovell (1961), Wallace (1965), Fogelman (1970) and Lunzer(1960c) also summarise studies of conservation, Elkind & Flavell (1969) present further theoretical discussions of what is involved in the development of conservation, and many other books and pamphlets on Piaget's work include discussions of conservation concepts. A general summing-up of Piaget's developmental psychology is given by Piaget & Inhelder (1969).

No attempt need be made here to summarise Piaget's theories nor his findings on the spontaneous development of conservation. These are expounded by Piaget (1952), Piaget, Inhelder & Szeminska (1960), and Piaget & Inhelder (1941) and are described and discussed as relevant in later chapters of this thesis.

Nor does it seem necessary to summarise here studies in which training was given in order to develop understanding of conservation but these may be cited as basically effective or ineffective. There have been relatively few studies which have effectively induced conservation. Smedslund (1961 b,c & d) and Wohlwill & Lowe (1962), for example, show how difficult it is to provide learning situations for young children which speed up their understanding of conservation. A few training studies, however, have had some success in accelerating conservation, for example, Beilin (1965), Gruen (1966), Wallach, Wall & Anderson (1967); but the understanding of conservation developed in these studies did not generalise to other attribute situations. Other studies showing varying degrees of success in accelerating conservation are Churchill (1958), Smedslund (1961 e & f), Frank (in Bruner et al, 1966), Sigel, Roeper & Hooper (1966), Brison & Sullivan (1967), Kingsley & Hall (1967), Galperin (1968), Gelman (1969), and Rothenberg & Orost (1969); but many of these studies did not test for generalisation to other attribute situations.

Piaget himself has not been particularly concerned with accelerating development of conservation, however Inhelder & Sinclair (in Mussen et al 1969) have reported Genevan learning experiments designed to study the psychological processes underlying the "transition from one structure to the next" as evidenced, for example, in the development of conservation. These studies raise the question of the influence of initial understanding. Inhelder & Sinclair have found that "much depends on the initial level of the subject: the lower his level, the more a new acquisition tends to stay limited either to the particular problem or to the particular field;" (p.20) and they have concluded that "possession of an elementary invariant (conservation of number) is a prerequisite of success - even of partial success - in learning experiments." (p.19).

When the investigations reported in the present thesis were designed, the common conclusion was that on the whole training procedures had not been successful (e.g. Flavell (1963) p.377, and Almy, Chittenden & Miller (1966) p.42). Experimental procedures were seen to fail to produce cognitive change except with children very near the age at which the conservations usually develop. Intensive training with such children had sometimes accelerated the development of conservation but concepts developed by special training were found to differ from concepts developed naturally. Induced conservation was shown where differences were not great, but was not generalised to new situations and was given up in the face of seemingly incompatible experience. Different explanations, also, were reported to have been given by "trained" and "natural" conservers; "trained" children had cited empirical findings where "naturally" conserving children had given deductive explanations. No attempts had been made to develop understanding of conservation in educationally subnormal children.

Inhelder's (1943) studies of the spontaneous development of conservation in subnormal children raised the question of sequence. She found that the order of acquiring concepts of conservation of substance, weight, and volume was the same in mentally retarded as in normal children, though their developmental speed differed and conservation of volume was present only in the least backward of the retarded children. She reported that conservation of volume was never found without conservation of both substance and weight, nor conservation of weight without that of substance, while conservation of substance occured without conservation of weight and volume and conservation of substance and weight without that of volume. Inhelder did not study the development of conservation of other attributes in the mentally retarded and so did not relate conservation of number, distance, length or area to the sequence conservation of substance before weight before volume.

The research reported in this thesis was concerned with six central questions.

First, can understanding of conservation be developed in educationally subnormal children by instruction?

Second, if so, by what means?

Third, is such conservation generalised and durable?

Fourth, is there a uniform sequence in the development of conservation in ESN children?

Fifth, in what ways is a child's recognition of conservation influenced by the particulars of the situation facing him?

Sixth, how is a child's response to teaching influenced by his initial level of understanding?

These six questions were raised repeatedly throughout the investigations but each investigation prompted various subsidiary questions which willbe discussed in the different chapters.

In addition to addressing these questions, the research is likely to have implications for the education of mentally retarded children and for understanding mental development in general. While the practical value of accelerating more able children's understanding of conservation is open to question, it can reasonably be argued that it is important to teach children who might otherwise never develop a generalised understanding of conservation.

The investigations will be described fully later but at this juncture it seems appropriate to elaborate some general points: those of the basic design of enquiry, the situations used, the method of teaching, the criterion for understanding of conservation, and the children studied.

The basic design of each of the 5 investigations was similar, in that (a) children were pre-tested for recognition of conservation, (b) an experimental group of nonconservers - matched to a control group - was given instruction, and (c) the children were post-tested in unfamiliar, inequality, and different-attribute situations two or three times over a period of weeks and months. As the investigations progressed conservation was studied in an increasing range of situations and various teaching procedures were tried; later investigations made use of findings of earlier ones. These investigations are reported in detail in Chapters 2 to 6 in the order in which they were carried out, and questions arising in earlier investigations were often taken up and answered in subsequent ones.

The situations used throughout were Piaget-type problems involving number, substance, length, distance, area, weight and volume, see Piaget (1952), Piaget, Inhelder & Szeminska (1960), Piaget & Inhelder (1941). Standard problems were presented to all the children but flexibility in questioning each child ensured clear communication. The children were asked questions in terms familiar to them and using materials of a sort also familiar to them. For example, questions of volume were expressed in terms of room inside block buildings and space taken up in containers of water.

The teaching procedures were not derived from a single theoretical approach, rather, an eclectic one was used. Many sided instruction was given based on analysis of the components of conservation tasks and children's performances in the problem situations. A variety of experiences and explanations were given in the standard teaching schemes. The emphasis throughout was on the individual needs of different children. At basis the investigations involved studies of individual children and changes in their performance.

Concerning the criterion for conservation, a child was considered to understand conservation if he recognised, without rechecking, the continuing equality of 2 sets of material throughout changes in appearance and also gave reasons for his judgments in a range of problem situations. Typically, a child starts out by judging 2 sets of material equal with regard to a particular attribute (e.g. number, length, or weight), then one of the 2 sets is transformed in full view of the child who is asked whether the 2 sets are still equal with regard to the attribute in question and is also asked why he thinks what he does. The main point to be made here is that the criterion included recognition and also explanation of conservation.

The children studied in the 5 investigations were drawn from schools for the educationally subnormal. Their IQs (as assessed by Medical Officers or Educational Psychologists on the Terman Merrill or Weschler intelligence scales) ranged from 42 to 81 and they were aged between 8 and 16. In all, 317 children were pre-tested and of these 102 nonconservers were given instruction.

Each investigation is reported in a separate chapter of the thesis where detailed procedures and findings are recorded and then discussed. These details are given for each investigation because deliberate changes were introduced in the procedures in order to clarify the influence of situational and instructional variables. It would have been pleasing to make these chapters shorter than they are. But it was felt that full descriptions and even some duplications of descriptions were justified in the interests of clarity.

CHAPTER 2

THE DEVELOPMENT OF UNDERSTANDING OF WEIGHT CONSERVATION *

I. INTRODUCTION

Investigation One was addressed to the following questions. Given educationally subnormal children who show no evidence of having a concept of weight conservation, is it possible to teach them this concept and, if so, how can the teaching best be done? Answers to these questions are important on both practical and theoretical grounds. On the practical side, many ESN children complete their schooling without having developed a concept of weight conservation and they may, thereby, be at a disadvantage in various everyday activities such as shopping, cooking, and working with materials in bulk. On the theoretical side, conservation is a logical operation central in Piaget's theory of cognitive development: the attainment of ability to conserve is seen as a landmark in the development of logical thought which is free from perceptual domination. By attempting to teach a concept of conservation to slow-learning children it was hoped to discover if and how it is possible to modify or accelerate the acquisition of a logical structure.

Following Piaget (e.g., Piaget & Inhelder (1941) Chapter 2, especially p.57), a child can be said to have a concept of weight conservation if he recognises that the weight of an object remains unchanged during changes in form so long as nothing is added or taken away: a pound of flour remains a pound whether it is in a bag or tipped into a bowl or spread over a bread board. Piaget regards the concept of conservation as central to the concept of weight; thus no 'true' concept of weight is present until the judgment of weight is independent of changes in appearance, until weight is recognised as constant throughout changes in shape. However, a distinction can be made between a concept of weight and a concept of the conservation of weight; and this distinction seems important in teaching ESN

* The substance of this chapter is reported in a paper, Br. J. educ. Psychol., 39, 245-252.

children. It may well be said that a child has no 'true' concept of weight prior to a concept of conservation of weight, but conservation can be regarded as a separate mental process because a perceptually based concept of weight, inaccurate though it may be, develops before a concept of weight conservation, as does also a consistent understanding of the meaning of words like 'heavier', 'lighter', 'weighs more', 'weighs less', and a kinesthetically based awareness of weight. Such judgments about, and understanding of, weight may not indicate a 'true' concept of weight, but it would seem that a teacher needs to develop these kinesthetic judgments before introducing the complexity of conservation of weight throughout transformations in shape. So in attempting to teach a concept of weight conservation it seems important, in the early stages, to treat weight independently and to develop a concept of weight as distinct from substance. Weight, the result of gravitational pull, is not the same as substance, amount of "stuff"; and children who do not have a concept of weight abstracted from perceptual judgment of size tend to associate large with heavy and small with light. In objects of equal weight, the sensations of pressure are not always the same; and many children are surprised when they discover, by means of a balance, that a ball of plasticine and a pancake of the same amount of plasticine weigh the same. Conservation of weight can only develop when apparent variations are understood to be subjective. So, in teaching a concept of weight conservation, a teacher ought clearly to distinguish weight from perceptual appearance.

Research has been carried out which attempts to advance conservation concepts (of number, substance, weight, length) in normal children using various different training procedures, see for example Smedslund (1961a, b, c, & d), Wohlwill & Lowe (1962), Beilin (1965). Generally, as Flavell (1963 p. 377) and Almy, Chittenden & Miller (1966 p.42) have pointed out, studies which have attempted to develop concepts of conservation have had little success. Experimental work so far has not made clear just what is involved in the transition from nonconservation to conservation, and much of the early evidence would seem to indicate that cognitive change of this sort can not be induced by short-term training procedures.

Among training studies, relatively few have been concerned with the concept of weight conservation; the majority have dealt with conservation of number or substance. However Smedslund (op. cit.) carried out several experiments attempting to teach conservation of weight. In the first experiment of his series, although subjects improved from pre- to post-tests, there was no significant difference either between differently trained groups of subjects or between trained and control groups. In another experiment, subjects learned to give conservation of weight answers as a result of practice in predicting and testing the weight of objects after transformation. But these subjects were found to give up their acquired conservation, where "natural" conservers did not, when the experimenter surreptitiously stole a piece of plasticine as he changed an object's shape. In a third experiment, Smedslund attempted to foster conservation of weight in non-conservers by providing experience with the unreliability of perceptual size cues. This method had virtually no effect. Apart from Smedslund's studies, there have been a few other attempts to teach a concept of weight conservation. Kingsley & Hall (1967) reported success in teaching weight conservation by experimentally "training conservation through the use of learning sets". They analysed the teaching of a concept of weight conservation into a hierarchy of subtasks and gave demonstrations and then explanations continually eleciting their subjects' active participation in tasks simple to complex. As a result, their subjects learned a concept of conservation of weight which was generalised to conservation of substance. Smith (1968) also reported successful teaching of a concept of weight conservation. He found that a "verbal rule instruction" method improved conservation performance: this method included demonstrations of reversibility as well as emphasis on the significance of addition/subtraction.

As far as the writer knows, no experiments have been carried out on the teaching of conservation of weight to educationally subnormal children. The present study attempted to teach this concept to such children in order to clarify elements important in the development of the concept and to discover how to further the acquisition of such concepts by slow learning children.

II. PROCEDURE AND RESULTS

Subjects were drawn from a school for educationally subnormal children. Forty-four children aged between 13 and 16 with IQs between 42 and 79 were pre-tested for conservation of weight judgments in the usual Piaget-type situations. Twelve children, who gave non-conservation judgments on all the questions of the pre-test, were selected for special study. Six experimental subjects were matched as closely as possible by six control subjects with respect to chronological age and IQ. Between matched subjects, thedifference in age was never more than six months, in IQ never more than 5 points. Children of higher and lower IQ, and higher and lower chronological age, were included for teaching. The six experimental group subjects were taught and then post-tested twice. When the experimental group was given the post-test for a second time, the six control group subjects were re-pre-tested; then they too were taught and post-tested twice. Eight months later, eleven of the twelve original subjects were followed up and further tested.

The materials used were simple and familiar to the children: plasticine, book, pencil, model car, feather, apples, margarine, "Lego" blocks, balloons, lead ball, rice, rubber, plastic cups, boxes, chocolate, cheese, a two-pan balance, wooden and metal 1cm. unit cubes, clear perspex containers, and water.

Throughout the entire investigation the experimenter was aware of the need to avoid giving children any extraneous or inadvertent clues by gesture, expression, or tone of voice and every attempt was made to avoid giving such clues.

(i) Pre-testing.

The standard pre-test procedure was as follows.

(1a) Which is heavier, an elephant or a mouse?

(1b) Which is lighter, this model car or this feather? (handling concrete objects)

(1c) Which weighs more, this book or this pencil? (handling concrete objects)

(1d) Which weighs less, a bus or a bicycle ?

Only if children correctly answered the above questions (as did all but one of the children pre-tested) would they be asked the following conservation questions.

(2) Here are two balls of plasticine (approximately $1\frac{1}{2}$" in diameter), do they weigh the same, are they equally heavy?

(3) (After agreement of equality in weight) If I do this (cutting one ball in half, deliberately not saying 'cutting' or 'halving') to mine and keep my pieces, will your share and my share still weigh the same, still be equally heavy?

(4) Now I'll make two balls again. Do they weigh the same, are they equally heavy?

(5) (After agreement of equality in weight) If I do this (cutting one ball into quarters) to mine and keep my pieces, will your share and my share still weigh the same, still be equally heavy?

(6) Now I'll make two balls again. Do they weigh the same, are they equally heavy?

(7) (After agreement of equality in weight) If I do this (rolling plasticine out into a long snake) to mine, will your share and my share still weigh the same, still be equally heavy?

(8) Now I'll make two balls again. Do they weigh the same, are they equally heavy?

(9) (After agreement of equality in weight) If I do this (flattening one ball into a disc) to mine, will your share and my share still weigh the same, still be equally heavy?

The same wording was used in all cases when asking the initial questions of conservation. However in trying to discover the children's reasons for their judgments (reasons being important in ascertaining a genuine concept of conservation), the procedure was more flexible. Many of the children had difficulty in expressing or finding reasons for their judgments, even when their judgments were correct, consequently these children were drawn out with questions unbiased but adapted to the child and situation. Care was taken that the children would understand the questions as they were intended, that they could correctly use the terms 'heavier', 'lighter', 'weighs more', 'weighs less', 'weighs the same', 'equally heavy'. Language was simplified and gestures were used to clarify the questions asked.

Throughout the pre-test the experimenter made all the transformations in full view of the children. The subjects did not manipulate the transformations of the materials themselves. After a subject made a judgment, the experimenter made only non-committal remarks and, in an unchallenging manner, asked the child why he thought what he did.

Each subject was seen alone for about ten minutes and sat opposite the experimenter at a small table in a quiet room of the school. The subject's performance on the pre-test was recorded on a standard form and, as far as possible, the child's exact comments were taken down.

The criterion for consistent nonconservation was a failure to recognise equality of weight after transformation in shape, that is, a failure to recognise this in every one of the pre-test transformations while also giving a clear indication of which portion was considered heavier and for what reason. Failure to recognise conservation of weight was exhibited in a variety of ways. For example, both times a ball of plasticine was cut, one child said the uncut ball was heavier "because a whole is more" and then, when one ball was rolled longer or squashed flat, he said the ball was heavier "because the ball is fatter and harder". In contrast, another child said the pieces "look more heavier" for the first two transformations and then said the ball "is bigger and heavier" for the last two. In most cases the ball uncut, unrolled or unflattened was considered heavier but in a few cases the changed portion was judged of greater weight; in several cases children were inconsistent and judged first the ball but later the transformed portion as heavier. In every case it was clear that the subject realised that all the pieces of the transformed ball were included for comparison yet still did not recognise equality of weight.

Reasons for judgments of conservation, taken as evidence of genuine concepts of weight conservation, included: 'it's the same plasticine still', 'you can fix it back up together again', 'you haven't took any off'.

Of the forty-four E.S.N. children pre-tested, sixteen were consistent nonconservers, six were conservers in some situations only, twenty-one were consistent conservers, and one child was too disturbed to be satisfactorily assessed.

(ii) Teaching the Experimental Group.

Six experimental group subjects (five boys and one girl whose respective ages and IQs were: 13 years, 72; 13 years, 60; 13 years, 77; 15 years, 66; 15 years, 74; and 15 years, 59), were matched with six control group subjects (three boys and three girls whose respective ages and IQs were: 13 years, 76; 13 years, 58; 13 years, 76; 15 years, 61; 15 years, 72; and 15 years, 61). The six experimental subjects were given training designed to develop the concept of weight conservation. Each experimental group subject was taught alone for one session of fifteen to thirty minutes. Although the method of teaching was flexible and was adapted to the individual child, it was kept within standard limits and included standard manipulations, demonstrations, and explanations. Because the primary aim was to see whether a concept of weight conservation could be taught to E.S.N. children, varied experiences were given to the child: it seemed premature to opt for a particular method.

Each teaching session involved a sequence of eight steps. Step 1. Subjects experienced, with eyes closed, the muscular feel of objects of different relative weight and gave judgments of heavier or lighter for two plasticine balls, and then, for a book and a rubber. Step 2. Subjects were asked to equalise the weight of two initially unequal plasticine balls, and then, unequal amounts of rice in two identical plastic cups. The experimenter pointed out the need of a balance for accuracy and, where necessary, how to use a balance. Step 3. Subjects tried on the balance large-light and small-heavy objects (e.g. small filled box and large empty box, small lead ball and large balloon) and then, objects of identical appearance but different content (e.g. identical plastic cups, one filled the other not, and apparently identical plasticine balls, one with lead inside it). The experimenter emphasised the distinction between weight and size and that judgment could not be made by appearance only. Step 4. Subjects balanced two four-piece "Lego" cubes, then broke one into halves and balanced it against the whole cube; then further broke it into quarters and balanced it. The subjects then put the broken cube back together again and repeated the procedure while the experimenter counted the pieces of "Lego" to bring out the continuing equality. As this type of discontinuous material was found by Smedslund (1961f) to be conserved before continuous, it was used here to bring out conservation. Step 5. Subjects manipulated reversibility of continuous material, i.e. subjects cut a whole ball of plasticine into pieces, halves and then quarters, put them back together again, and did this several times balancing the portions throughout while the experimenter emphasised that the weight was unchanged. Step 6. Subjects carried out continuous transformations of plasticine i.e. subjects turned one ball from snake to ring to disc and back again to ball while the experimenter stressed the identity of the plasticine. In order to increase the generality of the concept of conservation, identity was pointed out in several different transformations. Step 7. Subjects were asked to predict whether changing the shape of one of two plasticine strips would change the balancing of the two strips, and then, whether cutting would change the balancing weight of a block of margarine, and last, the same for two balanced apples if one were cut. Here linguistic encoding by the subject preceded the manipulation which tested the prediction. Step 8. Finally, the experimenter used Smedslund's method of inducing conservation by creating "cognitive conflict". Smedslund (1961e) induced "conflict" by simultaneous deformations and additions or subtractions in which apparent changes with deformation were in the opposite direction from changes with addition or subtraction: and he found that such "conflict" led to conservation of substance. So in the present study, after two balls of plasticine were recognised as of equal weight by the subject, one was rolled out into a snake: if the subject judged one portion to be heavier, the experimenter "subtracted" a small piece of plasticine, asked the subject if the ball and the snake were then of equal weight or not, and if not, which the subject thought was heavier, and emphasised that some of the plasticine had been taken away from one of the previously equal portions so that, even if it appeared heavier, it was not heavier if some plasticine had been taken away from it. The subject was, therefore, faced with a portion still perhaps perceptually larger but emphasised as containing less plasticine. Then the piece was put back on, equalising the weights of plasticine. Next, after the subject agreed that two balls were of equal weight one was flattened into a disc and a small extra piece of plasticine was added to whichever portion the subject judged lighter. This again was meant to create "cognitive conflict" if the one that still appeared lighter obviously had been given more plasticine. The extra piece was then taken away and the portions emphasised as of equal weight. A form of Smedslund's subtraction/addition process was carried out even if the subject judged the ball and snake, or ball and disc, to be equal first; and since Smedslund (1962) found that the subtraction/addition sequence must precede the addition/subtraction sequence in order to develop conservation, that order was followed here.

As indicated above, a combination of active manipulation and verbal representation was used throughout the teaching. Experiences were discussed and clarified. Observation, prediction, and reinforcment were also included. Since it was thought that different children might learn the same concept in different ways, and that generalisation would be more likely to develop if varied experience were given, a variety of methods and materials was used in the teaching. The importance of actual addition or subtraction of material for any change in weight was brought out in several steps; perceptual seduction was countered. Identity likewise was emphasised in several situations. Identity was particularly stressed because nonconservers are said to centre on a single aspect not co-ordinating multiple relations, and there appeared to be a double question involved in the conservation situations, i.e. whether the weight and material were the same as in the original form (identity) and whether that was equal to the object of comparison (equivalence). Finally, the need for an external measure was brought out in order to free children from misleading perceptual appearances; a balance scale was introduced as an elementary measure of weight not necessitating transitivity.

On step 1 in the teaching session, two experimental group subjects had great difficulty in distinguishing relative weight by muscular feel, even though the differences were substantial. On step 2, three of the six subjects did not know to add or subtract some plasticine in order to make the weights equal; all but one subject knew how to use the balance, but only one subject spontaneously used it when equalising the portions. On step 3, all six experimental subjects, experiencing the conflict, accepted the distinction between size and weight. On steps 4 and 5, as on step 3, all six subjects showed great surprise but recognised conservation when they counted pieces and/or used the balance. On step 6, four experimental group subjects were still very surprised when they realised the conservation but, by step 7, all but two made predictions of conservation. In step 8, the subtraction/addition demonstration confirmed the conservation of weight for all six subjects.

(iii) Post-testing.

The first post-test was given to each subject two weeks after the teaching session, and the second post-test, two weeks after that. Each subject was seen alone for about ten minutes. The standard post-test procedure was similar to that of the pre-test but included some new materials and situations to test whether a generalisable concept had been developed rather than a specific response. Questions demanding inequality judgments, as well as questions on new materials, were included to reveal whether there was, for reasons other than that of a genuine concept of conservation, any agreement to sameness after transformation. Subjects were required to give simple judgments of inequality and also judgments of conservation of inequality of weight, a generalisation of the concept of weight conservation. Throughout, subjects were asked to give reasons for their judgments.

The actual wording of the post-test was the same as that of the pre-test. Items 2 to 8 were repeated but in item 9 a twist of plasticine rather than a disc of plasticine was made; then chocolate, one piece to be cut in half, and then cheese, one piece to be cut in thirds, were introduced. Finally, unequal balls of plasticine were presented; first the larger was cut in half, then the smaller was cut in quarters and last both larger and smaller were cut in halves. Again all transformations were made in full view of the subjects and gestures were used to clarify the questions. Noncommittal remarks were made after the children's reponses and a record was made of each child's judgments and reasons.

On their first and second post-tests all six experimental group subjects made conservation of weight judgments throughout; the subjects gave conservation judgments on the familiar, unfamiliar and inequality transformations. The reason usually given for conservation was that of identity in the sense that 'it is still the same' plasticine, chocolate, or cheese; in two cases reversibility was the reason given, e.g. "you can make it back again", "you've only cut it, you can put it back same."

On the repeat pre-test, given to the control group when the experimental group subjects did their second post-test, all six control group subjects consistently gave nonconservation judgments.

(iv) Teaching the Control Group.

The control subjects were then taught in exactly the same way as the experimental group had been. On step 1 of the teaching, all six control group subjects were able to distinguish relative weight by muscular feel. On step 2, three subjects did not know to add or subtract plasticine in order to equalise the weights and two subjects did not know how to use the balance; none used the balance until it was suggested. On steps 3, 4, 5 and 6 all the subjects were very surprised but finally accepted perception could be misleading. On step 7, one subject failed to predict conservation and two others only very hesitantly predicted conservation. On the last step, all six subjects clearly recognised the significance of the subtraction and addition of material.

On their first and second post-tests, carried out exactly as the experimental group post-tests had been, all six control group subjects gave conservation of weight judgments throughout; the subjects made conservation judgments on the familiar, unfamiliar, and inequality transformations. For their conservation judgments, three control group subjects gave the reason of identity in the sense of 'it is still the same material' and three gave the reason that 'nothing had been taken away', a version of the identity reason.

(v) Retention Study.

In the retention study, carried out eight months later, the eleven available subjects were again given the post-test for weight conservation. Then, in order to see if the retained concept of conservation would be generalised further, the subjects were tested for conservation of volume by means of the situations Piaget has used to study interior and occupied volume. (e.g., Piaget, Inhelder and Szeminska (1960.) Chapt. 14). To ensure that subjects distinguished questions of volume from weight, the experimental situations and the wording of the questions were different for the two attributes and, where possible, judgment on the basis of the different attributes was made mutually exclusive - the separation of volume from weight was made by weighting plasticine balls. In addition, after the subjects had been asked questions of weight conservation, the following operational distinction of simple volume and weight was required of them.

Here are two boxes each with something different inside (lighter bigger box, heavier littler box)

(1a) Find and give me the box which takes up more room, takes up more space.

(1b) Find and give me the box which weighs more, is heavier.

(1c) Find and give me the box which takes up less room, takes up less space.

(1d) Find and give me the box which weighs less, is lighter.

Here are two plasticine balls (one heavier bigger, one lighter littler)

(2a) Find and give me the ball which takes up more room, takes up more space.

(2b) Find and give me the ball which weighs less, is lighter.

(2c) Find and give me the ball which takes up less room, less space.

(2d) Find and give me the ball which weighs more, is heavier.

After the eleven subjects had correctly made the distinction between weight and volume, they were given the conservation of volume problems. Piaget's interior volume situations were introduced first. Three transformations of one of a pair of 36-wooden-unit-cube buildings, previously recognised as of equal volume, were made; and for each transformation the subjects were asked the following three questions. (a) Does my building still have as much room in it? (b) Do our buildings have equally much space? (c) Are our buildings the same size, equally big?
Next, the occupied volume situations were presented using both discontinuous (36 metal unit cubes) and continuous (plasticine) material. After recognitions of equality followed by transformations, the subjects were asked these three questions. (a) Would my rock (or share) still make the water rise the same, rise equally far, if put in this (container)? (b) Would our rocks (or shares) leave as much space for water in these (containers)? (c) Would our rocks (or shares) take up equally much room in these (containers)? For the conservation of volume situations, as for the weight post-test situations, each subject's judgments and reasons for them were recorded.

The eleven subjects available for the retention study still gave correct conservation of weight judgments with appropriate reasons for them. The most frequently given reason for conservation was, again, identity in the sense of 'it is still the same' plasticine, chocolate, or cheese. Another reason, 'nothing has been added/nothing has been taken away', was also given but less frequently. These eleven subjects, as well as making conservation of weight judgments, made conservation judgments in the Piaget volume situations. Generalisation of the concept of conservation from the weight to the volume situations appeared immediately in six subjects; four subjects hesitated in the first lengthening transformation only, and one subject gave conservation judgments in the occupied volume situations but not in the prior interior volume situations. Individual subjects gave the same reasons for conservation in the volume situations as they had given for conservation of weight. Some of the children who in the weight situations stated that nothing had been added or subtracted, in the conservation of volume situations gave, in addition, conservation of number reasons. Children who gave the reason of sameness of material gave only that reason throughout.

III. DISCUSSION

The experiment showed that it is possible to teach a concept of conservation of weight to previously consistently nonconserving E.S.N. children. After a single teaching session, all twelve of the subjects gave conservation of weight judgments, with reasons for them, in new as well as familiar situations whereas they had not done so before. Eight months later the subjects still maintained conservation of weight; their experimentally induced concepts of conservation proved to be durable as well as generalised and supported by reasons. It can therefore be argued that a genuine concept of conservation had been taught. It might, however, be suggested that the subjects had only learned a verbal response. For example, the words "if I do this to mine - - - ?" might be said to be a cue for "yes" answers, and judgments of sameness for reasons of identity. There are four grounds for rejecting such an interpretation. (1) In the conservation of weight post-test situations, subjects were required to give negative as well as positive judgments, i.e., judgments of inequality as well as equality. They did this correctly.

(2) The reasons the children gave were not as similar as the classification into categories might suggest. For example, the "nothing has been added or taken away" category includes reasons such as "you haven't took none off it", <u>or</u> "you haven't put nothing to it", <u>or</u> "you still got all the pieces" - not a single taught verbal response. In the "same stuff" category, additional comments, such as "you just put it different", indicated more than verbal learning. (3) As the reason of identity was only one of several reasons brought out in the teaching situations and was not a practised response, and as varied active experience of conservation of weight was given, it would seem unlikely that a simple verbal response alone was learned. (4) In the retention study, very different expressions followed the "if I do this to mine - - - ?" opening in the volume and weight situations. Although it is true that, in the weight situations, the wording was always the same ("will your share and my share still weigh the same, still be equally heavy?"), in the volume situations questions on interior and occupied volume were worded entirely differently and the "if I do this to mine - - - ?" was a very distant cue indeed. There is, therefore, evidence that more than a verbal response had been learned.

No attempt was made to "extinguish" conservation responses by surreptitiously removing material because it seemed unfair to subject retarded children to such a situation. The fact that both Kingsley & Hall (1967) and Smith (1968), on the basis of their experimental results, reject resistance to extinction as a means of distinguishing "taught" from "genuine" conservation lends support to the omission of this as a test for the genuineness of the conservation taught in the present experiment.

Experience during the eight months after the teaching session might have resulted in the development of conservation of volume independent of the teaching of conservation of weight and so it cannot be stated conclusively that the taught conservation of weight was generalised to volume, although such generalisation is suggested by this study. Although it is unlikely that a concept of conservation in the volume situations would have been shown when conservation of weight in the pre-test situations was not, and although it was reported that conservation of volume had not been taught during the eight months, both of these factors need to be controlled before generalisation of taught conservation can be said definitely to occur.

Although this experiment, and an earlier one carried out by the writer on the conservation of substance, showed that it is possible to teach ESN children a concept of conservation and how, in general, one can accelerate such a concept, further work would be needed to determine any specific effective and essential aspects of the teaching as well as the extent of the influence of the teaching. The present study did not reveal whether the crucial influence was a particular experience, some variety in experiences, ordering of experiences, or the interaction of these and perhaps other factors; nor did it reveal the relative importance of identity, addition/subtraction, reversibility or other explanations; nor did it indicate which method of teaching was most effective. Likewise the present study did not reveal the extent to which a taught concept of conservation may be generalised; certainly the results of the retention study indicated that a taught concept of conservation of weight may be generalised to volume, but the limits of generalisation were not established. These, and related, questions were studied in subsequent investigations and are discussed in later chapters.

On the question of effective and essential elements in the development of conservation, it was the writer's impression from working with the children in the present investigation that more than one particular experience or explanation was responsible for the development of a concept of weight conservation. Piaget (1968) writes that conservation involves more than identity alone and depends on a total system of operations involving reversibility and compensation as well as identity. Piaget further argues that "quantitative operational" identity, i.e. identity in the sense of 'nothing has been added or subtracted', rather than "qualitative pre-operational" identity, i.e. identity in the sense of 'same material', is necessary for the development of conservation. He sees this "quantitative identity operation +0-0=0", as a necessary yet not sufficient foundation for conservation. In short, Piaget argues that the system of operations which is essential for the development of conservation includes this "quantitative" identity and also reversibility and compensation. Although subjects in the present experiment gave "qualitative" identity reasons alone, as well as "quantitative" identity reasons alone, in explanation of conservation, it cannot be said conclusively that identity alone provided sufficient basis for conservation. Subjects may have been aware of compensation and/or reversibility as well as identity even though they cited only identity explicitly in giving reasons for conservation judgments; ESN children lacking verbal fluency are unlikely to express more than a single reason for their judgments.

To conclude, the results of the first investigation showed that it is possible to develop a concept of weight conservation in ESN children using a teaching method which includes active manipulations by the learner and verbal representations with emphasis on identity, subtraction/addition, and reversibility.

CHAPTER 3

THE DEVELOPMENT OF UNDERSTANDING OF VOLUME CONSERVATION*

I INTRODUCTION

The purpose of Investigation Two was to reveal whether and how it is possible to teach a wide age range of educationally subnormal children a concept of conservation of volume in Piaget-type situations, and whether such a taught concept of conservation will be generalised from the volume situations to weight and substance situations, and if conservation of volume can be taught before conservation of weight and/or substance is recognised.

Such a study of the development of a concept of volume conservation is of both practical and theoretical interest. It is of practical importance in that a large number of educationally subnormal children do not recognise conservation in Piaget-type volume situations and an effective method of teaching such children this concept could enable them to solve elementary problems which arise both in classroom and out of school situations. An understanding of volume conservation is basic to any further work involving volume, for example in arithmetic, in cooking, in gardening; it is important wherever the children are faced with containers to fill and objects to be packed away, in school, at home, or in their later jobs. The study is of theoretical interest as it investigates two issues of central importance to Piaget's developmental theory: the notion of a fixed order in development and that of generalisation. The two issues are distinct but related. The investigation was designed to reveal any natural orfunctionally necessary sequence of stages in the development of conservation of substance, weight, and volume, i.e. to test whether conservation of substance and weight are prerequisites for conservation of volume. The question of generalisation of the taught concept of conservation was studied in relation to these attributes said to arise earlier in the sequence.

*The substance of this chapter is reported in a paper, Br.J. educ. Psychol., 40, 55-64.

In this investigation Piaget's interior and displacement volume situations were used. These situations were concrete and appropriate for educationally subnormal children. Piaget, in studying children's concepts of volume conservation, introduced problems involving objects made of wooden and metal unit-cubes (The Child's Conception of Geometry, Chapt. 14) and objects made of plasticine (Le developpement des quantites physiques chez l'enfant, Chapt. 3).

In presenting the volume conservation problems (The Child's Conception of Geometry, Chap. 14), Piaget started from a construction whose shape had been reproduced by the children, with or without help, and built other constructions out of the same unit-cubes changing the form of the base while the children watched. The children were then asked whether there was as much room in the new as in the old construction or whether there was more or less room and whether the same cubes which now formed the new could be used to remake a construction like the original and exactly the same size. Biaget next asked the children questions on the conservation of volume when a solid object was immersed in water. He built a block of unit-cubes at the bottom of a bowl of water while the children noted how the water level rose. The children were then asked if they thought the level would change if the arrangement of unit-cubes was modified. In addition to questions about water level, the children were asked whether the cubes would continue to take up the same amount of space in the water or whether there was as much room for water as before.

This second situation, the one in which a block of unit-cubes was immersed in water, would enable questions to be asked on interior, occupied, and complementary volume. Interior volume Piaget described as volume defined by boundary surfaces, occupied volume as the amount of space taken up by an object in relation to other objects around it, and complementary volume as the volume of the water displaced. Conservation of the last two volumes, Piaget said, was present if the children anticipated that the water level would remain unaltered.

Piaget found that children recognised conservation of interior volume before conservation of occupied volume. This Piaget suggested was because conservation of occupied volume necessitates more than simple qualitative operations, involves not only logical but mathematical multiplication, and further implies the infinite subdivision of continuous space. Piaget argued that: at first, logical multiplication and compensation of relations between dimensions enables the conservation of interior volume; qualitative co-ordinations of subdivisions and changes of position occur without any use of measurement. Then, reconstruction and spontaneous measurement involving logical transitivity allow more accurate compensations. Later, measurement involving unit iteration develops, boundaries are measured in three dimensions, the relations between lines and areas bounding a solid and its volume are established, mathematical multiplication enables the calculation of volume, and conservation of volume relative to its surrounding space is understood. Thus Piaget described the development of understanding of volume conservation as from a qualitative conservation of interior volume, through the achievement of simple metrical operations, to the mathematical calculation of volume and conservation of occupied and complementary volume.

For the purposes of this investigation a child was said to have an understanding of volume conservation if he recognised conservation in all the interior and displacement volume situations presented to him, whether or not he was able to measure and calculate volume mathematically. A child was said to understand conservation of interior volume if he recognised that the room inside a unit-cube building remained unchanged during changes in the shape of the building so long as nothing was added or taken away. He was said to understand conservation of displacement volume if he recognised that the space taken up by metal unit-cubes and plasticine and the water level likewise would remain unchanged during transformations of the objects immersed in water. The concept of volume conservation taught was strictly a concept of conservation and not a concept of volume which entailed mathematical calculation or an explanation of density. A full understanding of volume may require an understanding of density and the compression and decompression of matter (as Piaget discussed in Le developpement des quantites physiques chez l'enfant, Chapt, 8) as well as the mathematical calculation of volume, but such a concept of volume is distinct from, and not necessary for, the development of a concept of conservation in interior and displacement volume situations. It is this latter concept that is more important for educationally subnormal children to learn.

The recognition of volume conservation is a limited aspect of an understanding of volume but it is basic to any fuller understanding. Piaget himself (The Child's Conception of Geometry, p.355) recognised that volume in one sense is based on an elementary understanding not entailing measurement and mathematical calculation. Such an elementary understanding of volume conservation is no less genuine because it is limited nor need it be restricted to interior volume. An understanding of volume is likely to be gradually developed and extended and the recognition of conservation in interior and displacement situations, without explicit understanding of density, compression/decompression, measurement, or mathematical multiplication, is a step in the gradual development of fuller understanding.

To develop a basic understanding of volume conservation, only situations where conservation of volume holds true need to be considered. To introduce questions involving popped corn, or water ice and steam, or collapsed containers would unnecessarily complicate the teaching for educationally subnormal children.

As far as the writer knows no other investigators have attempted to teach volume conservation though several investigations have been carried out on the natural development of a concept of volume conservation, see for example Beard (1962), Elkind (1961b), Lovell & Ogilvie (1961b), Lunzer (1960d).

II PROCEDURE AND RESULTS

One hundred and four educationally subnormal schoolchildren aged between 8 and 16 with IQs between 46 and 80 were pre-tested for conservation in Piaget-type substance, weight, and volume situations. Thirty children who gave nonconservation judgments in <u>all</u> the volume situations were chosen for special teaching. Sixteen of these children, who failed to recognise conservation of substance and weight as well as volume, were paired - matched for chronological age and IQ; six other of these children, nonconservers of weight and volume, were likewise matched and eight others, nonconservers of volume only, were so paired. Between experimental and control subjects differences in age were always less than 9 months, in IQ usually less than 6 points. The thirty children taught ranged in age from 9 to 15 and in IQ from 46 to 75. The fifteen experimental group children were taught and then post-tested twice. When the experimental group was given the post-test for the second time, the fifteen control group children were re- pre-tested; then they too were taught and post-tested twice. Five months later, twenty-nine children were again post-tested.

The materials used were: plasticine, orange drink, four 100ml beakers, one low wide dish, two 50ml beakers, four 25ml beakers, balance scale, lead weights, rice, wooden 1cm unit-cubes, metal 1cm unit-cubes, four perspex containers 4"x4"x3", water, marking pen, four boxes of the following internal dimensions: 6x3x2high cms, 12x3x1high cms, 6x3x2high cms in two parts  , 6x3x2high cms in four parts  , "lego" cubes, perspex boxes 5"x3"x2".

Throughout the investigation the experimenter tried to avoid giving any extraneous or inadvertent cues by gesture, expression, or tone of voice. The situations and questions were presented so as not to bias the children's responses. The procedure was standard yet flexible. Care was taken that children understood the questions as they were intended. The children's answers to the different wordings of the questions were recorded separately for each wording in order to check for consistency and understanding.

(i) Pre-testing.

The pre-test included questions on conservation of substance, weight, and volume in order to select for teaching children with different degrees of understanding of conservation i.e. children who failed to recognize conservation of volume, weight, and substance, children who failed to recognise conservation of volume and weight but recognised conservation of substance, and children who failed to recognise conservation in the volume situations only. As well as finding children with no concept of conservation of volume who might be taught that concept, the pre-test was designed to reveal any naturally occurring order or sequence in the development of concepts of conservation in E.S.N. children. Likewise the pre-test was meant to provide for the later investigation of generalisation of taught conservation from the volume to the weight and substance situations, i.e. to provide a record of the presence or absence of conservation judgments for substance and weight as well as volume prior to the teaching. In brief, the pre-test provided for answering the following questions: Is there a naturally occurring sequence in the development of conservation, conservation of substance before weight before volume, in E.S.N. children? Can a concept of conservation be taught out of this generally recognised sequence, i.e. can conservation of volume be taught before concepts of conservation of weight and substance have been attained? And, will a taught concept of conservation be generalised to other attributes?

To ensure that children distinguished volume from weight from substance when answering the conservation questions and gave judgments for appropriate reasons, the pre-test situations as well as questions were different for the different attributes, and, where possible, judgments on the basis of different attributes were made mutually exclusive. The separation of volume from weight was made by differentially weighting same-volume balls of plasticine; conservation for weight was distinguished by divorcing heaviness and size by differentially weighting same-volume balls and identically weighting different-volume balls of plasticine. Weight situations separated substance and volume questions. Different materials were introduced and different transformations were made in different attribute situations although certain materials and transformations were similar throughout the pre-test for control and consistency on one dimension of difficulty. The word "amount" was not repeated for attributes other than substance and the actual wording of the questions in the substance, weight and volume situations was entirely different in each case. (See Chapter appendix for details of the pre-testing procedure)

Piaget's conservation problems were presented. Liquid as well as plasticine was used in testing for conservation of substance because in past studies some children have been found to conserve for the one substance, liquid, and not for the other. Conservation of volume was investigated in displacement situations as well as in Piaget's internal volume situation because children have been found to conserve for interior before occupied or complementary volume. The displacement situations entail the consideration of volume in relation to something outside the object itself; the situation is clearly different from that involving conservation of substance. Continuous material, plasticine, was used as well as discontinuous, blocks, in displacement volume situations in order to preclude conservation for the reason of number alone where conservation of volume was required. The large number of blocks likewise mitigated against number conservation only. Discontinuous material, blocks, was used in both the internal and the displacement situations to ensure that any differences in difficulty would be due to the volumes considered and not to the fact that discontinuous material is often conserved before continuous.

Judgments of <u>in</u>equality as well as of equality were required throughout the pre-test in order to reveal any agreement to sameness after transformation for reasons other than that of a genuine concept of conservation. In addition perceptual as well as conceptual judgments were called for. Although it was recognised that the question "look the same" may be ambiguous and a distinction between reality and appearances might not be made, the "look the same" question provided a counter suggestion to test the stability of the conservation judgments.

Operational understanding not just verbal recognition of equality on the different attributes was tested before making any transformation or asking any conservation questions i.e. children were asked to select and give the experimenter objects equal on a named attribute. This made it clear that the children would understand the conservation questions as the experimenter intended them. For every transformation the conservation question was asked in three different ways; care was taken to eliminate any misunderstanding by wording the same question in several ways.

Throughout the pre-test the experimenter made all the transformations in full view of the children. The children did not manipulate the transformations of the material themselves but they could see materials being returned to their original form. After a child made a judgment, the experimenter made only non-committal remarks and in an unchallenging manner asked the child why he thought what he did. Children's explanations of their judgments were taken as evidence of conservation or nonconservation.

Each child was seen alone for about twenty minutes and sat opposite the experimenter at a small table in some fairly quiet place in the school. The child's performance on the pre-test was recorded on a standard form and, as far as possible, the child's exact comments were taken down.

The criterion for total nonconservation was a failure to recognise equality in any attribute (substance, weight, or volume) after transformation in shape in <u>every</u> one of the pre-test transformations while also giving a clear indication of which portion was considered greater or less and for what reasons. The criterion for partial nonconservation was nonconservation in one or two of the three attribute situations i.e. the failure to recognise equality after transformation in <u>every</u> situation involving any particular attribute or attributes. In other words, a child who was classed as a total nonconserver would judge every object after transformation as more or less in amount, weight, or volume while a child who was classed as a partial nonconserver would, in particular attribute situations only, judge a transformed object as greater or less and would recognise conservation in other attribute situations.

Nonconservation was exhibited in a variety of ways. In some cases the transformed portion, and in other cases the original, would be judged greater or less. Such differences in judgments were found within the same child, between different children, and within and between different attribute situations. In failing to recognise conservation, children were not necessarily consistent in their judgments of greater or lesser portions nor in their reasons for their judgments, but in every case it was clear that the child realised all the previous material was included for comparison.

Reasons for conservation judgments taken as evidence of genuine concepts of conservation included: the recognition of identity of material, amount, or weight, that nothing had been taken away or added, and the recognition of the possibility of reversing the transformation or of similarly transforming the as yet unchanged portion, or a clear statement that the portions were equal before and so must still be equal. There was variety in the children's justifications of conservation judgments too, both in the type and number of reasons given.

Of the one hundred and four educationally subnormal children pre-tested, thirty-nine were total nonconservers, one gave nonconservation answers in all but the liquid substance situations, seven were nonconservers of weight and volume but conservers of substance, eleven gave nonconservation answers in the volume situations only, one gave conservation answers for all but the interior volume situations and five of the six displacement volume transformations, one gave conservation answers for all but the weight and interior volume situations, one conserved for all but weight and solid substance, one conserved for all but interior volume and solid substance, five recognised conservation for all but interior volume, one recognised conservation for all but displacement volume, two recognised conservation in later but not in earlier transformations of different materials and thirty-four were total conservers.

The thirty-nine total nonconservers ranged in age from 8 to 16 and in IQ from 45 to 75, the seven nonconservers of weight and volume ranged in age from 10 to 16 and in IQ from 52 to 75, the eleven nonconservers of volume only ranged in age from 10 to 16 and in IQ from 64 to 74, and the thirty-four total conservers ranged in age from 10 to 16 and in IQ from 55 to 80. The lowest mental age to be found among children who recognised conservation in <u>every</u> situation was 5.7 (CA 10). The highest mental age to be found among children who <u>failed</u> to recognise conservation in <u>every</u> situation was 9.5 (CA 15). The results of this pre-test indicate the extent of individual differences in the development of conservation concepts in E.S.N. children. (These mental ages can be compared with those found by other experimenters presenting similar problems to mentally retarded subjects. Hood (1962) found 6.6 the lowest mental age among conservers of substance and 9.8 the highest mental age among nonconservers of substance. Mannix (1960) found no completely operational thinking in children with a mental age of less than 6.8 nor completely preoperational thinking in children with a mental age greater than 6.5.)

Although no single child has been studied longitudinally to reveal any natural sequence in the development of conservation of different attributes and although no simple pattern of conservation responses was found in a cross section of E.S.N. children, the sequence conservation of substance before weight before volume was verified in general for E.S.N. children. Only three children recognised conservation of an attribute later in the sequence but not conservation of a prior attribute i.e. except in three cases conservation of volume did not appear until after conservation of substance and weight nor did conservation of weight develop before conservation of substance.

The sequence was generally found to hold but was not unexceptionable.

While this pre-test revealed that for the majority of E.S.N. children conservation develops in the generally agreed sequence substance before weight before volume, it did not reveal any sequence for conservation of interior before displacement volume as has been found by Piaget(The Child's Conception of Geometry, Chapt. 14). Rather, seven children gave clear conservation answers in the displacement volume situations but gave clear nonconservation answers in the interior volume situations. The pre-test was repeated with these seven children and the reversal of Piaget's order was again found, i.e. the children responded the same as before. It was thus shown that the conservation of displacement volume in the absence of conservation of interior volume was not the result of practice in the pre-test situations nor the result of any individual merely momentary confusion or variability.

The question of differences in conservation shown in interior and displacement volume situations was clarified in a subsequent investigation but certain points need to be mentioned here. It was clear that the children were aware of the distinction between interior and displacement volume questions. Not only was there a demonstration and explanation of displacement before any questions about conservation of displacement volume were asked in situations entirely different from those for interior volume, but also all the children selected objects appropriately when asked to do so in relation to making water rise as well as in relation to taking up space. All the children understood the displacement volume questions as the experimenter intended them. The fact that seven children gave conservation answers in the displacement volume situations but not in the interior volume situations was further evidence that the distinction was made; likewise there was a single child who conserved in the interior but not in the displacement situation. Thus, the pre-test situations and questions effectively distinguished displacement and interior volume and conservation of displacement volume was several times recognised before conservation of interior volume and only once was conservation of interior volume recognised before conservation of displacement volume.

The displacement volume situations in this pre-test were different from those described by Piaget (The Child's Conception of Geometry, esp.pp. 358 and 375-6). It is not clear precisely how Piaget presented the problems to each child i.e. whether he actually made the transformations in each displacement volume situation, but no comparision object is reported to have been present in any displacement volume situation and the fact that the objects were immersed in water would make it unlikely that any transformation would be carried out because if it were the child could observe the effect on the water level and answer the conservation question on the basis of immediate perceptual experience. The displacement situations in this experiment were presented to each child in the following way: The actual transformation was made and a comparison object was present in every case so that the situations were consistent with those for conservation of substance, weight, interior volume, etc. The objects were not in the water at the time of transformation in order not to prejudice judgments but they had previously been in water and the children clearly understood what was meant when questioned on the objects making the water level rise, taking up space. Other than in these three main conditions, i.e. the presence or absence of actual transformations, comparison objects, and present immersion in water, the displacement situations in Piaget's experiments and in this experiment were similar, for example the same materials, thirty-six 1cm metal unit cubes and plasticine, were used and similarly worded questions asked. The interior volume situations were likewise similar to Piaget's in these respects. However, less obvious differences, for example the different number or type of movements in making transformations, i.e. different actions or different permutations of unit cubes, may influence the results.

Conservation was clearly not an all or none development, rather it was often recognised for some but not for other attributes (substance, weight, or volume), in some but not in other situations (e.g. liquid not solid substance), and for some but not all transformations of the same attribute (e.g. 6x3x2 building in two parts not 12x3x1 building). Two particularly good examples of the children's thinking were the following: Clearly distinguishing substance from interior volume, one child said "it's the same amount so there's the same room in it - no, there's more room in it". Another child asserted "it's the same plasticine but it takes up more space".

(ii) Teaching the Experimental Group.

Fifteen experimental group children (eight total nonconservers whose respective ages and IQs were: 14 yrs 5m, 57; 12 yrs 5m, 66; 12 yrs 0m, 60; 11 yrs 1m, 46; 10 yrs 5m, 67; 10 yrs 2m, 62; 9 yrs 11m, 70; 9 yrs 4m, 73; three non-conservers of weight and volume whose ages and IQs were: 14 yrs 7m, 61; 14 yrs 7m, 52; 11 yrs 10m, 63; and four nonconservers of volume only whose ages and IQs were: 14 yrs 9m, 64; 14 yrs 5m, 74; 13 yrs 2m, 72; 10 yrs 8m, 70) were matched with fifteen control group children (eight total nonconservers whose respective ages and IQs were: 14 yrs 5m, 58; 12 yrs 10m, 64; 12 yrs 2m, 61; 11 yrs 10m, 52; 10 yrs 4m, 71; 10 yrs 1m, 61; 10 yrs 4m, 66; 9 yrs 5m, 70; three nonconservers of weight and volume whose ages and IQs were 15 yrs 3m, 75; 14 yrs 2m, 55; 12 yrs 0m, 65; and four nonconservers of volume only whose ages and IQs were: 14 yrs 8m, 70; 14 yrs 4m, 70; 12 yrs 11m, 74; 10 yrs 8 m, 71). Of the fifteen experimental group children eight were boys and of the fifteen control group children six were boys.

The fifteen experimental group children were given teaching designed to develop a concept of volume conservation. Physical, not mathematical, volume was considered; the development of a concept of conservation of volume as a concrete operation in Piaget's sense was not seen to necessitate mathematical calculation by linear dimensions. Conservation in Piaget's interior volume situation was taught and then conservation of volume in the displacement situation. The displacement situation, while it is complex involving not only conservation and equivalence of volume but also recognition of the relation between volume of object immersed and volume of liquid displaced, does enable simple recording of occupied volume in a finite situation; the water level can be marked off before and after an object is immersed or transformed, the object taking up room in a container of water rather than in unbounded space.

A repetition of the pre-test situations in every teaching session was designed to provide, first, a check that subjects were still nonconservers at the start of the teaching sessions and, second, information as to when in the teaching conservation developed in these subjects and whether conservation was generalised from the earlier teaching situations to the later.

The children were given varied experiences, involving different manipulations of concrete materials in different situations and verbalisation of several reasons and empirical findings, in order to develop a broad understanding of volume conservation. Each child was taught alone for one session of approximately thirty minutes. Although the method of teaching was flexible and was adapted to the individual child, it was kept within standard limits and included set experiences and explanations. Each teaching session involved a combination of manipulating reversibility, filling containers with and counting discontinuous material, measuring displacement and verbalising reasons for conservation (including reversibility, identity, and compensation) and empirical findings (such as the distinction between appearance and reality and the results of measurement.

The teaching began with the consideration of interior volume. A transformation of one of two recognised-as-equal wooden-block buildings was made, i.e. one of two 6x3x2 high buildings was made 12x3x1 high and the pre-test questions for interior volume were asked. Then the experimenter demonstrated and the child manipulated reversibility. After a preliminary check that the child could give the correct number of blocks up to 36, the experimenter demonstrated and the child filled two boxes shaped to hold the 6x3x2 and the 12x3x1 block buildings counting the same number of blocks into each box. Throughout these demonstrations and manipulations, the experimenter emphasised verbally that there was as much room in each transformation, equally much space inside, only the shape was different. The sameness or identity of the material and amount was pointed out and that nothing had been added or taken away. That the building could therefore be made back the same as it was before was likewise stated and also that changes in one direction were compensated for by changes in another direction. The same demonstrations, and manipulation of reversibility and counting of identity, and verbal explanations were repeated for the second and third transformations of the 6x3x2 wooden block buildings, i.e. for the separating of one building into two and then four overlapping parts, but the child was encouraged to take the leading role in manipulating and explaining conservation in the interior volume situations.

The teaching continued with the consideration of displacement volume. After an initial demonstration of displacement, i.e. after 36 metal blocks were immersed in a dish of water and the water rise recorded, a transformation of one of two recognised-as-equal metal-block 'rocks' was made, i.e. one of two 4x3x3 high 'rocks' was made 6x6x1 high, and the pre-test questions for displacement volume were asked. The experimenter then demonstrated and the child marked on the container that the water level rose the same for the two different shaped 'rocks'. Again the child counted that the same number of blocks was in each 'rock'. Throughout the marking off of water levels and counting, the experimenter emphasised verbally that these showed that the transformation took up equally much room, left as much space for water, merely looked different, i.e. the experimenter emphasised the distinction between reality and appearances, and the child was encouraged to express the evidence for equality, i.e. to state that the water rose the same, equally far. For the second and third transformations of the 4x3x3 metal block 'rocks' i.e. for the separation of one 'rock' into two and then four overlapping parts, the child was again helped to record and count and then verbally express the evidence for the continuing equality of displacement volume.

The teaching ended with the further consideration of displacement volume using plasticine instead of blocks. After an initial demonstration of displacement of water by plasticine, a transformation of one of two recognised-as-equal-in-volume-though-not-weight plasticine balls was made, i.e. one of the two balls was made into a ring, and the pre-test questions for displacement volume were again asked. The child then manipulated reversibility and marked that the water level rose the same for the transformed as for the original plasticine. Throughout, the child was encouraged to give reasons for conservation including the recognition of identity, reversibility, and compensation as well as to make empirical statements including the result of marking off water levels and its significance. The child did the same for the second and third transformations of the plasticine ball, i.e. for the cutting of one plasticine ball into two and then four pieces.

All of the experimental group children gave nonconservation answers to the questions on the first transformation in the opening interior volume situation. Twelve children said there was more room or space inside the 12x3x1 high transformation, two that there was more in the 6x3x2 high building, and one judged first the 12x3x1 and then the 6x3x2 greater. The children pointed out as justification for their judgments that one looked "bigger" or "longer" or "fatter" etc.; each child's answers were very similar to those he had given on the pre-test. Thirteen of the children counted up to thirty-six blocks meaningfully and without help, two did so with help. Filling the boxes as well as counting, however, required much time and attention. For the second and third transformations in the interior volume situation, ten children recognised conservation and gave reasons for their judgments. Six children gave as a reason the fact that there were the "same blocks" all the time, one child gave the reason that there was the "same amount of blocks", and three children gave as a reason the fact that the building "could be put back the same as before". Five children did not recognise the conservation of interior volume and pointed out not only that one building looked "bigger" but also that the blocks were "put more" or "spread". Three children thought there was more room or space inside the transformed building and two that there was more inside the original.

Eight of the experimental group children recognised conservation in the displacement volume situation i.e. eight of the fifteen children had learned and generalised conservation from the interior volume situation. Five children gave reasons for their conservation judgments; two of these children said that there were the "same blocks", one that there were the "same amount of blocks", and two said the building could be "put back the same as before". Three children gave no reasons for their conservation judgments. Six of the experimental group children did not recognise conservation of displacement volume; three of these said the 6x6x1 high transformation took more space than the original 4x3x3 high rock, two said the 4x3x3 rock took more, and one child judged first the 4x3x3 and then the 6x6x1 rock to take more space. These six children said in justification of their judgments that one was "bigger" or "wider" or "squarer" or "fatter". One child said he did not know in answer to the questions of displacement volume; he said that he would "need to try it". For the second and third transformations in the displacement volume situation, all fifteen children recognised conservation and gave reasons for their judgments. Seven children gave as a reason the fact that there were the "same blocks" four children gave the reason that there was the "same amount of blocks", and four children gave as a reason the fact that the rock "could be put back the same as before".

Fourteen of the experimental group children recognised conservation in the displacement volume situation when plasticine was used i.e. fourteen children had developed a concept of conservation and recognised conservation of displacement volume when a new material, plasticine, was introduced instead of blocks. Thirteen of these fourteen children who recognised conservation gave reasons for their judgments; one child gave no reasons. Seven children pointed out that there was the "same plasticine" still, three children that there was the "same amount" of plasticine, and three children that the plasticine "could be rolled back the same as before". One child still did not recognise conservation of displacement volume and pointed out that the ball looked bigger. For the second and third transformations of plasticine in the displacement volume situation, all fifteen children recognised conservation and gave reasons for their judgments. Eight children gave the reason that there was the "same plasticine", four that there was the "same amount" of plasticine, and three that the plasticine could be "rolled back the same as before".

The results in the teaching of a concept of volume conservation, like the results of the pre-test, revealed that the development of conservation is gradual and individual differences important. There were individual differences in the speed of learning, in the pattern of learning, and in the reasons for learning. The amount of repetition of manipulations and verbalisations that was necessary varied for different children; some children learned to recognise conservation within twenty minutes, others needed forty minutes. Conservation was not recognised by all children at the same point in the teaching nor was it maintained in the same manner thereafter. No relation was found between the point at which conservation was recognised and whether the child had been a total or partial nonconserver. Different children found different manipulations and explanations to be the most convincing; some children found recording the water level particularly convincing, others found manipulation of reversibility or counting for identity most helpful. Identity reasons for volume conservations judgments were the most frequently given by the children; reversibility reasons were next most frequently mentioned. The reasons individual children gave could be easily categorised as identity, reversibility etc. and children gave predominantly one reason or another. This does not mean, however, that all children gave only one reason throughout the teaching session. Generally one main reason was repeated but another reason was often also mentioned. Reversibility and identity were quite frequently cited as subordinate reasons to each other; compensation likewise was cited as a subordinate reason. The experimenter felt that there were differences in why and what the individual children learned; younger children appeared to need most the information given while older children seemed to need to have their attention appropriately directed.

When perceptual judgments, i.e. judgments on the basis of appearance not reality, were made the transformed object was usually judged greater, but this was probably due to the particular transformations made.

Care was taken in teaching to emphasise volume conservation rather than number conservation. No child counted to give number conservation answers alone. Likewise in the displacement situations in which plasticine was used, fourteen and then fifteen children recognised conservation of continuous material. Conservation answers were given for the right, i.e. for volume, reasons.

(iii) Post-testing.

The first post-test was given to each child one week after the teaching session, and the second post-test, one week after that. Each child was seen alone for about twenty minutes. The standard post-test procedure was similar to that of the pre-test but included some new situations to test whether a general concept had been developed rather than a specific response learned; both familiar and new materials, transformations, and names of objects were introduced to test for generalisation and not just a learned response. Questions demanding inequality judgments also were included to reveal whether there was, for reasons other than that of a genuine concept of conservation, any agreement to sameness after transformation. Unequal quantities were presented not only to check that recognition of sameness was not a response to any and every situation but also to test for further generalisation; children were required to give not only simple judgments of inequality but also judgments of conservation of inequality of volume. Throughout the post-test, the children were asked to give reasons for their judgments; both judgments and reasons were recorded. The stability of the children's conservation judgments was tested by the experimenter's pointing out perceptual differences; in giving a counter suggestion the experimenter simply emphasised appearances and did not mislead the children. All transformations were made in full view of the children; gestures were used to clarify the questions. Noncommittal remarks only were made after the children's responses.

The actual wording of the post-test was similar to that of the pre-test. The pre-test questions and situations were repeated in the post-test and the questions in the new situations were worded similarly. (See chapter appendix for details of the post-testing procedure). In the second situation of the post-test, new material, "Lego" blocks, was introduced, new transformations made, and new verbal labels used but the problem was similar to that in the teaching, i.e. equality was to be recognised after transformation. In the fourth situation, that involving unequal metal-block transformations, new verbal labels and new transformations were introduced; and new containers, though not new blocks, were used. The problem, i.e. that of recognising and conserving for inequality, was different from that in the teaching. The sixth situation, the final new situation in the post-test, was again an inequality situation but one involving inequality of volume and equality of weight. No new material was introduced but new transformations and new verbal labels were used. In the rest of the post-test the familiar pre-test situations were presented. The preliminary choosing of two objects equal on a given attribute from among four objects was, however, omitted from each situation as it was known from the pre-testing that these children could understand the questions as they were intended. No negative options were given in the questioning, i.e. the questions were not worded 'same or different'. This might make it more likely that children would give conservation answers in the equality situations but it might likewise make it less likely that children would recognise inequality and conservation in the inequality situations.

On their first and second post-tests all fifteen experimental group children made conservation of volume judgments throughout; the children gave conservation judgments on the familiar/unfamiliar and inequality transformations. The reason most frequently given for conservation was that of identity in the sense of its being the same material or same amount of material still, a reason quickly put into words by the children. Another reason frequently mentioned was that of reversibility in the sense of putting the material back the same as it was before. Compensation reasons were also mentioned but less frequently. The fact that nothing had been added or taken away was never given as a reason for conservation judgments although this reason too was pointed out in the teaching. The reasons the children gave on the post-tests were similar to those they had given during the teaching session, i.e. each child mentioned the same reason or reasons in justification of his conservation judgments in the post-tests as he had in the teaching. The reasons the children gave on the first and second post-tests were likewise similar; each child's identity or reversibility or compensation reasons were just as clearly and fully expressed on the second as on the first post-test.

The eight children who had been total nonconservers generalised their taught concept of conservation of volume to weight and substance; they recognised conservation in the weight and substance as well as volume situations and seven gave clear reasons for their judgments. The three children who had not recognised conservation of weight or volume but had recognised conservation in the substance situations also generalised their taught concept of conservation of volume and recognised conservation in the weight situations as well; all three gave reasons for their judgments. These eleven children understood and considered the different attributes in question, i.e. the children gave conservation judgments for the appropriate attribute in each situation. One girl, for example, before giving judgment asked "weigh you said, not space? "

All fifteen experimental group children developed a concept of conservation and gave conservation judgments in all the volume, weight and substance situations presented, but there were clear individual differences in their responses. Some children were very hesitant in expressing a reason for their conservation judgments; other children gave reasons easily. There were differences in clarity, speed, and number of reasons given. Four children cited several reasons for conservation, three gave two reasons, seven gave just one reason throughout, and one boy was reluctant to give any reasons. All the children had been encouraged to give as many reasons as they could and the experimenter had given them adequate time to express their understanding. Those who gave the most reasons were the slowest at the start; and those who were quickest to express reasons generally gave only one reason throughout.

More than a simple single verbal response was learned. Although the children's reasons could be categorised as identity or reversibility or compensation reasons, there were noticeable differences in the way the reasons were expressed. Identity type reasons were worded in different ways, e.g. it's still the same toy or building and not just it's the same blocks or plasticine or amount; reversibility type reasons were likewise expressed in different ways, e.g. you could move the other one the same and not just you could make it back the same as before. Compensation was also explained in different ways appropriate to the different transformations, but compensation reasons were often not as clearly expressed as the identity and reversibility reasons were. The children frequently used the word bigger when they could not give the exact word needed to describe the dimensional differences, that is they would say bigger when they meant longer or wider etc., e.g. that one's fatter but the other's bigger or that one's bigger this way (pointing) and that one's bigger this way (pointing). Several children chose to demonstrate their reasons, for example, reversibility was enacted by one boy in particular throughout the post-test.

On the repeat pre-test, given to the control group when the experimental group children did their second post-test, all fifteen control group children consistently gave nonconservation judgments still. The explanations they gave for their nonconservation judgments were similar to those they had given in the original pre-test, e.g. it's longer so it has more room in it, it's fatter so it'll make the water go up more.

(iv) Teaching the Control Group.

The fifteen control group children were then taught in exactly the same way as the experimental group children had been.

All of the control group children, like the experimental group children, gave nonconservation answers to the questions on the first transformation in the opening interior volume situation. All fifteen children judged the 12x3x1 high building to have more room or space inside it and pointed out as justification for their judgments that the 12x3x1 building looked "bigger" or "longer". As was true of the experimental group, each control group child gave answers for the first transformation like those he had given on the pre-test. All fifteen control group children counted up to thirty-six blocks meaningfully and without help. Filling the boxes as well as counting again required much time and attention. For the second and third transformations in the interior volume situation, twelve children recognised conservation and eleven of these gave reasons for their judgments. Three children gave as a reason that there were the "same blocks", five that there was the "same amount" of blocks, and three that the building "could be put back the same as before"; one child gave no reasons at all. Three of the fifteen children did not recognise conservation of interior volume and pointed out that one building was "oblonger" or "fatter" or "in one piece". All three of these children thought there was more room inside the original building.

Nine of the control group children recognised conservation in the displacement volume situation i.e. nine of the fifteen children had learned and generalised conservation from the interior volume situation. Eight of these nine children gave reasons for their conservation judgments; one said there were the "same blocks", three that there were the "same amount" of blocks, three that the rock could be "put back the same as before" and one that one was "longer but the other taller". One child gave no reasons for her conservation judgments. Six of the fifteen control group children did not recognise conservation of displacement volume; two of these children judged the 6x6x1 transformation as taking up more space and four judged the 4x3x3 rock as taking more. In justification of their judgments these six children pointed out that one was "bigger" or "fatter" or "higher" or "spread". For the second and third transformations in the displacement volume situation, all fifteen children recognised conservation and gave reasons for their judgments. Two children gave the reason that there were the "same blocks", seven that there was the "same amount" of blocks, five that the rock could be "put back the same as before", and one child gave the reason that the rock "weighs the same still".

Eleven of the control group children recognised conservation in the next displacement volume situation when plasticine was used i.e. eleven children had developed a concept of conservation and recognised conservation of displacement volume when a new material was introduced instead of blocks. Nine of these eleven children who recognised conservation gave reasons for their judgments; two children said that there was the "same plasticine" all the time, three that there was the "same amount" of plasticine, three that the plasticine could be "rolled back the same as before" and one child said that one portion was "longer but the other fatter". Two children gave no reasons at all for their conservation judgments. Four children still did not recognise conservation of displacement volume; two said that the transformed portion took more space because it was "longer" or "bigger" and two said that the original ball took more because it was "fatter" or "bigger". For the second and third transformations of plasticine in the displacement volume situation, all fifteen children recognised conservation and gave reasons for their judgments. Four children gave the reason that there was the "same plasticine", seven that there was the "same amount" of plasticine, and four that the plasticine could be "rolled back the same as before".

The results in the teaching again revealed that the development of conservation is gradual and individual differences important. Again there were individual differences in the speed, the pattern, and the reason for learning i.e. in the amount of repetition necessary for different children, in the point at which conservation was recognised and the way it was afterwards recognised by different children, and in the manipulations and explanations found most convincing by different children as evidenced in their own explanations. No relation was found between the point at which conservation was recognised and prior total as against partial nonconservation. Identity reasons were again the most frequently given by the children, reversibility reasons the next most frequent and then compensation reasons. As was true of the experimental group children, control group children generally gave one main reason throughout the teaching session occasionally mentioning subordinate reasons. Again, the experimenter noticed differences in the children's overall reactions to the teaching; some children appeared to need much information and explanation while others seemed mainly to need their attention directed.

The particular transformations made seemed to influence the nonconservers' choice, e.g. when judgments on the basis of perceptual features were made in the first transformation of the interior volume situation, the 12x3x1 transformation was invariably judged greater.

When conservation was recognised it was again recognised for the right, (i.e. for volume) reasons; no children were recognising conservation of number or substance alone rather than volume.

On their first and second post-tests, carried out exactly as the experimental group post-tests had been, all fifteen control group children gave conservation of volume judgments throughout; the children made conservation judgments on the familiar, unfamiliar and inequality transformations. For their conservation judgments, the reason most frequently given by the control group children, as by the experimental group children, was that of identity, in the sense of its being the same material or same amount of material. Reversibility, in the sense of putting the material back the same as it was before, was, again, the next most frequently given reason for conservation. Compensation reasons were given by only one child. One other child mentioned the fact that nothing had been added or taken away in explanation of his conservation judgments; this reason, a version of the identity reason, had not been cited by any child in the experimental group. The reasons each child gave on the two post-tests were similar and similar again to those he had given during the teaching session.

The eight children who had been total nonconservers generalised their taught concept of conservation of volume to weight and substance; they gave conservation judgments with reasons for them in the weight and substance as well as volume situations. The three children who had not recognised conservation of weight or volume but had recognised conservation in the substance situations also generalised their taught concept of conservation of volume and recognised conservation in the weight situations as well; they too gave appropriate reasons for their conservation judgments.

Although all the control group children recognised conservation in all the situations presented, there were noticeable individual differences in their responses, as there had been among the experimental group children's responses. The explanations they gave differed in their clarity, fullness and speed with which they were given. All of the children gave reasons for their conservation judgments, one child gave several reasons, eight gave two reasons, and six gave only one reason throughout. The explanations of conservation given by the boy who mentioned several reasons were the most confused i.e. although more reasons were cited irrelevant arguments were also included.

Again there was evidence that more than a verbal response had been learned. Identity and reversibility reasons were worded differently by different children, several children enacted their reversibility reasons; compensation was expressed differently and appropriately for the different transformations.

(v) Post-testing with Revised Displacement Situations.

The thirty children, experimentals and controls, who had been taught and post-tested were further tested for conservation in revised displacement volume situations. (See chapter appendix for details). In their first and second post-tests these children had recognised conservation in the original displacement volume situations, as in all the other volume, weight, and substance situations, but there were reasons for testing the children in a revised displacement volume situation: The results of the pre-test, contrary to those of Piaget (The Child's Conception of Geometry Chapt.14), showed that some children recognised conservation in displacement volume situations before they did in interior volume situations; Piaget had found the reverse order. As Piaget's displacement volume situations were different from those in the present experiment, it seemed that differences in displacement volume situations might influence the recognition of conservation. Therefore a displacement volume situation more like Piaget's (whose displacement volume situation, as mentioned earlier, is not absolutely clear from the description in The Child's Conception of Geometry, Chap. 14) was also presented to the children in order to check that the taught concept of volume conservation was not limited, i.e. to check that the taught concept of conservation would be generalised and conservation recognised in the different displacement volume situations.

The revised displacement volume situations differed from the original displacement volume situations in three main ways: in the revised situations, no comparison object was present, no actual transformation made, and the object was immersed in water. Another difference was in the wording: the children were asked where the water would come to if an object were transformed rather than asked if the water would rise equally far, i.e. the wording of the question did not include any suggestion of sameness.

The children were tested for conservation in the revised displacement volume situations less than one month after their second post-test. The procedure, apart from the stated differences, was similar to that throughout the investigation. Each child was seen alone but for only about five minutes and each child's judgments, explanations, and resistance to countersuggestions were recorded. The materials were in the centre of the table, gestures were used to clarify questions, and non-committal remarks only were made after the child's responses.

All thirty children recognised conservation in the revised displacement volume situations and gave reasons similar to the reasons they had given on the first and second post-tests, i.e. all the experimental and control group children generalised and recognised conservation in all the new displacement situations. Their understanding of displacement volume conservation was not limited to the recognition of conservation in the original situations only.

All but three of the children without any hesitation recognised conservation in the new situations. Two children hesitated on the first transformation only, e.g. "lower water, no, the same, it's the same blocks", and one child had considerable difficulty at first in understanding the conservation problem which was more verbally less concretely presented in the revised displacement volume situation. After several repetitions of the problem this child, who had usually demonstrated rather than verbalised reversibility reasons for his conservation judgments on the previous post-tests, understood the questions and recognised conservation.

All but one of the thirty children gave reasons for their conservation judgments and reasons similar in most cases to those they had given on the first two post-tests. Five children, however, who had previously given reversibility reasons did not do so but gave other reasons when the revised displacement volume situations were presented, i.e. when reversibility was less appropriate as a reason for conservation judgments because no actual transformation had been made which could be reversed.

(vi) Retention Study.

In the retention study, carried out five months later, the twenty-nine children still at the school were again given the post-test for volume, weight, and substance conservation. This included the revised as well as original displacement volume situations. The revised situations were again presented last in the series of conservation situations but this time within a single testing session. The testing was carried out under the same conditions and exactly as it had been before. (See chapter appendix for details).

The durability of the concept of conservation developed in the children was evidenced by the fact that all twenty-nine children still recognised conservation in every situation presented to them and gave appropriate reasons for their conservation judgments. Even the one child who had never before given reasons for his conservation judgments this time gave a clear "it puts together again" reason for conservation. The most frequently given reason for conservation was, as before, identity in the sense of its being the same material or amount of material. Reversibility reasons were, again, next most frequently given. Reversibility, the possibility of putting the material back the same as it was before, was expressed or demonstrated nearly as often as identity reasons were given; compensation reasons and the fact that nothing had been added or taken away were infrequently mentioned. The reasons each child gave were similar to those he or she had given on previous occasions.

III DISCUSSION

This investigation of the development of understanding of conservation answered some questions, clarified others and raised still others. It answered the questions whether and how it is possible to teach a concept of volume conservation to educationally subnormal children. It likewise answered the question as to whether a taught concept of conservation would be generalised to different attributes and situations. Further, it showed that conservation of an attribute usually found later in the sequence substance-weight-volume can be taught before conservation of an earlier attribute is recognised. The investigation also clarified several points. The recognition of conservation in displacement volume situations may precede the recognition of conservation in interior volume situations. The development of a concept of conservation is not all or none. A diversified method of teaching conservation is important to develop a broad understanding. The question of particular elements essential in the development of a concept of conservation was not answered. Likewise the possibility of developing an understanding of volume conservation using a simplified teaching scheme remained to be investigated. Ultimately the investigation provoked the question whether a general teaching scheme can be devised to develop conservation of multiple attributes in one go.

The first question to be answered by this investigation was: can a concept of volume conservation be developed in E.S.N. children? The answer was yes. All thirty children given instruction which included counting for identity, manipulating reversibility, marking off water levels in displacement volume situations, and verbalising the three reasons of identity, reversibility, and compensation, learned and recognised conservation in all the interior and displacement volume situations of the post-test. More than a verbal response was learned. The children gave conservation judgments in unfamiliar and inequality situations as well as in the familiar situations. They made negative as well as positive responses. The reasons the children gave varied from several, providing an argument for conservation, to none at all. Some children demonstrated reversibility rather than putting their explanation into words. Many children gave a single reason for their conservation judgments, but these children rarely expressed their reasons in the same way for example, one child said "you just have to fix it up the same", another said "it counts up the same", another "it weighs the same", and another "when it was together it was the same". And finally, the children's conservation answers were given to questions worded quite differently; no simple verbal cue was given. Thus, it can be said that a genuine understanding of conservation developed in these children.

The concept of conservation developed in this investigation was a concept of volume conservation and not just one of number or substance conservation. The children understood the questions were of interior or occupied volume, e.g. some children even asked "room in it to run about in?" or "space you said, not weight?" They recognised conservation in situations involving continuous material where conservation for number alone would not apply and distinguished volume from weight and substance and gave appropriate responses in situations where judgments on the basis of different attributes were made mutually exclusive.

It is recognised, however, that though a genuine concept of volume conservation had been developed, the children's understanding of volume was limited. The teaching was designed to give the children an understanding of conservation in the Piaget-type interior and displacement volume situations and this it did. Such an understanding, while limited, is an essential step toward a fuller understanding of volume and is of practical importance; a concept of conservation in the interior and displacement volume situations provides a basis for the development of understanding of volume in an arithmetical as well as physical sense and is relevant to everyday problems the children meet.

The reasons the children gave could conveniently be described as identity or reversibility or compensation type reasons, but the differences in the actual reasons as expressed were not as clear as the classification might suggest. For example, the bare statement "it was the same before" could be a recognition of identity or reversibility and the explanation "you could make the other the same" could be described as an identity of action reason or a reversibility type reason. Bearing in mind the difficulty of classifying some reasons given by the children, and remembering also that the reasons given by the children were influenced by the reasons emphasised in the teaching, the relative frequency of the main types of reasons can be considered as possibly shedding light on the children's learning. Identity type reasons were the most frequently mentioned. This classification included "qualitative" identity reasons, e.g. identity of material, and "quantitative" identity reasons, e.g. nothing had been added or taken away. Reversibility type reasons were next most frequent; these included the mention of the possibility of reversal as well as a recognition that it was the same before. Compensation type reasons were the least frequently given. Taking "qualitative" and "quantitative" identity reasons separately the relative frequency of the reasons was: "qualitative" identity reasons most frequent, reversibility next, compensation next, and "quantitative" identity reasons least frequent. (This finding can be compared with that discussed in the earlier investigation of the development of a concept of weight conservation in relation to the role of "quantitative operational" identity in the development of conservation as suggested by Piaget (1968).)

Individual differences in the children's responses and reasons were great though all the children gave conservation judgments throughout the post-tests. The children's explanations differed in their clarity, in the number of reasons mentioned, and in the speed and ease with which the reasons were given. At one extreme of a continuum was the boy who would only say "I just know, I can't say why" and at the other extreme was a boy who would say "you can put it back the same, it's the same amount, one's more that way but the other's more up, two of them make one of them, put it in water and you'll see". The rest of the children gave one, two, three or four reasons and usually the same ones throughout the post-tests.

Whether the children's explanations reveal the degree of their understanding is an open question. The differences between the different children's verbal explanations of their volume conservation judgments do not necessarily reflect differences in their understanding of conservation. There need be no exact relation between the extent of a child's explanation of conservation and his grasp of the concept. Personality differences and differences in verbal fluency influence the expressing of reasons. Less articulate children, for example, often unhesitatingly recognised conservation and strongly resisted any counter suggestion yet gave only the briefest reasons for their conservation judgments, while more verbally fluent childrens' arguments sometimes were filled with irrelevancies. No necessary relation was found between the number of reasons given and other indications of degree of understanding. The clarity of a child's reasoning was not necessarily related to the number of reasons he cited nor to the ease with which he expressed them. The record of reasons given by each child gives a rough indication of the child's understanding but is not an exact indicator of degree of understanding.

Though degree of understanding and extent of verbal explanation may not always be positively related they need not always be unrelated either. It might be expected that, though all the children recognised, generalised and gave reasons for conservation, some children would understand conservation more fully than others and this understanding might or might not be reflected in their verbalisation of reasons for conservation. There are very likely to be individual differences in degree of understanding apart from verbal reasons though it is difficult to cite clear evidence of such differences. One boy argued "they are the same amount but they do not have the same room inside when you move them" and until he grasped the idea that one person could still fit in each block and thirty-six in the thirty-six blocks no matter how the blocks were arranged, he argued the difference between amount and space. This boy thought about the situation in detail before he recognised conservation of volume as distinct from amount. In contrast, one girl quickly learned to recognise identity of material and amount and gave conservation answers in the volume situations. She gave no sign of really thinking about the situation and the possibility that identity of material or amount might not necessitate conservation of volume. Understanding of conservation, as distinct from or related to verbalisation of reasons for conservation, varied from a clear appreciation of the physical situation and use of information given in the teaching, e.g. counting to prove conservation as well as stating that it is the same amount, to a simple knowledge of conservation and statement of the evidence for conservation, e.g. that it is the same material. All thirty children distinguished the attribute in question and recognised conservation of volume, weight, and substance, but some children were more aware of the implications, aware, for example, of the contrast between empirical evidence for conservation and perceptual appearances.

The question of differences in degree of understanding of conservation is of practical importance. Different children may well have benefitted to a different extent from the different aspects of the teaching; for example, older children may have needed their attention directed to the relevant aspects of the volume situations where younger children may have needed the physical experience of conservation in the volume situations. Though there was no conclusive evidence that this was so, the fact that different children in this investigation clearly found different experiences and reasons most convincing suggests that a varied teaching method which provides for such individual differences is important if a broad understanding is to be devloped in all children and if a further understanding of volume is to be built upon the concept of volume conservation taught. Clearer evidence of differences in degree of understanding of conservation with different teaching experiences and reasons was found in a subsequent investigation of the development of a concept of volume conservation.

The second question to be answered by this investigation, the question of generalisation of the taught concept of conservation from the volume to the weight and/or substance situations was also answered in the affirmative. All of the sixteen children who had previously been total nonconservers generalised and recognised conservation in the weight and substance as well as volume situations. Similarly, the six children who had previously been nonconservers of volume and weight generalised their taught concept of conservation from the volume to the weight situations. Thus, twenty-two children given full varied teaching generalised their understanding of conservation and gave reasons appropriate to the different attributes in question.

Clearly, the taught concept of conservation generalises from an attribute later in the generally accepted sequence substance-weight-volume to attributes earlier in the sequence, but the question arises as to whether such a taught concept would generalise forward as well as backward in the sequence, i.e. from an attribute situation where conservation is usually recognised earlier to an attribute situation where it is usually recognised later. The results in the prior investigation in which weight conservation was taught suggest that it would generalise to later attributes as well, but this would need to be tested under conditions more controlled than in the prior conservation of weight experiment.

Not only was the taught concept of conservation generalised from the volume to the weight and/or substance situations, but also conservation was recognised in revised displacement situations. The understanding of conservation developed was not limited to the original displacement volume situations. The reasons the children gave for their conservation judgments in the revised displacement volume situations were similar to those they had given in the original displacement volume situations if they were of the identity type, but if reversibility reasons had been given in the original situations other reasons more appropriate were suggested in the revised situations where reversibility was not actually enactable.

A third question answered in this investigation was the question whether conservation of volume can be taught before conservation of weight and/or substance is recognised. This was found to be possible. It was shown that conservation can be taught out of the generally accepted sequence substance before weight before volume. Total nonconservers and partial nonconservers learned to recognise conservation of the attribute last in the sequence before they had developed a concept of conservation of attributes earlier in the sequence. Understanding of conservation of weight and substance did not appear to be a prerequisite for conservation of volume, but understanding of conservation of weight and substance may develop concurrently when conservation of volume is taught. On their post-tests the children, who recognised conservation in the volume situations, always also recognised conservation in the weight and substance situations. No child in this investigation recognised conservation of volume but not conservation of weight and substance. In a subsequent investigation, however, when the teaching method was cut, four children recognised conservation in volume situations but not in all weight and substance situations.

It was found on the pretests in this investigation, and in the subsequent investigation, that the usually accepted sequence substance-before-weight-before-volume generally holds. The pre-test results revealed that conservation of volume is rarely recognised when conservation of weight or substance is not and conservation of weight rarely recognised when conservation of substance is not. Only three of the one hundred and four children pre-tested recognised conservation for attributes later in the sequence when they did not recognise conservation of earlier attributes. One child gave conservation judgments in the volume situations but not in the weight and substance situations, another conserved for volume and weight but not solid substance, and another for displacement volume but not weight. In addition, conservation of substance and weight appeared to develop closer together than conservation of weight and volume, i.e. fewer children recognised conservation of substance but not weight or volume than recognised conservation of substance and weight but not volume. To conclude, the sequence substance conservation before weight conservation before volume conservation, though not unexceptionable nor seemingly logically necessary, was generally found to hold.

A question clarified was whether conservation in a displacement volume situation is ever recognised before conservation in an interior volume situation. On pre-testing and repeated pre-testing, five children made conservation judgments in displacement but not in interior volume situations. Thus it appeared that conservation of interior volume need not precede conservation of displacement volume. Where Piaget (The Child's Conception of Geometry, Chap. 14) found that conservation is sometimes recognised in interior volume situations but not in displacement volume situations, this investigation revealed the reverse order is also possible. The particular displacement situations, however, were different and the question arose as to the effect of these situational differences on the recognition of conservation. The effect of different displacement situations was therefore studied in a subsequent investigation of volume conservation and some children were found to be nonconservers in the revised, i.e. the displacement situations more like Piaget's, though conservers in the original, i.e. the displacement situations like those in this investigation.

A point clearly brought out, and supported by findings in all the subsequent investigations, was that the development of understanding of conservation is not all or none. The results of both pre-testing and teaching in this investigation revealed that the development is gradual. There were, for example, children who recognised conservation of liquid but not solid substance as well as those who conserved for displacement but not interior volume and in the teaching session some children recognised conservation in one but not in the next situation. The need for a fairly full and varied teaching method seemed clear from this as well as from the fact that not all the children recognised conservation by the last teaching situation.

A question that remained to be answered was that of essential elements in the development of a concept of conservation. The importance of particular experiences, reasons, situations etc. would need further clarification. This investigation revealed that certain combinations of experiences, reasons and situations are effective in developing understanding of conservation in E.S.N. children but no essential elements were isolated. Nor was the relative importance of the different experiences, reasons etc. made clear.

Another question that would need further investigation is the possibility of simplifying or shortening the teaching. The omission of containers in the teaching of interior volume might facilitate the teaching. Filling the containers counting blocks made great demands on the children's attention and took up quite a lot of time for relatively little apparent return in understanding. The container situation included no actual transformation and verges on a situation where conservation would not apply. Thus it could justifiably be omitted. Although there are various ways the teaching method could be shortened, care would need to be taken to provide sufficiently varied teaching to develop a broad concept of conservation. It would seem that two or three experiences, reasons and situations need to be included in order to develop a sound understanding in all children.

To conclude, the second investigation showed that a concept of volume conservation can be developed in educationally subnormal children and that this understanding of conservation will be generalised to weight and substance situations. Using a varied teaching method which included three conservation experiences, reasons, and situations, thirty E.S.N. children were taught to recognise, generalise, and give reasons for conservation. The method used was found to be an effective way, though not necessarily the only or the best way, of developing conservation in children regardless of their prior understanding of conservation.

It might be possible to simplify or expand the teaching method and perhaps to isolate essential elements. The fact that development of conservation is not all or none, however, suggests that a fairly full method still would be most generally effective and the fact that any method more extended than that in this investigation would exhaust the children's concentration suggests that fuller teaching would necessitate an additional session. The teaching of volume conservation given in this investigation might provide one step in a series designed to develop a fuller understanding of volume. It would seem to be a method useful in the classroom and likely to be effective for group as well as individual teaching. The possibility of group teaching was in fact studied in Investigation Three.

IV APPENDIX

Pre-testing Procedure for Investigation Two.

1a. Here are four balls of plasticine (four same shape, one two times as large and one half as large as two same medium sized approximately $1\frac{1}{2}$" diameter balls)
Find and give me the balls which have the same amount of plasticine, which have as much plasticine as each other, which are fair shares of plasticine.
You have that ball and I have this one (two equal balls as chosen by subject or by experimenter)
Have we each the same amount of plasticine?
(After recognition of equality or making equal)
If I do this to mine (roll one ball into sausage approximately $3\frac{1}{2}$" long)
Is there still the same amount of plasticine,
Do we have fair shares of plasticine,
Do we have as much plasticine as each other?
Do our shares still look the same?
(Remake two balls and repeat questions cutting plasticine ball into 2 and then 4 pieces)

1b. Here are four glasses of orange drink (four identical 100ml beakers, two quarter full, one half full, one full)
Find and give me the glasses which have the same amount of orange drink, which have as much orange drink as each other, which are fair shares of orange drink.
You have that orange drink and I have this one (two equal drinks as chosen by subject or by experimenter)
Have we each the same amount of orange drink?
(After recognition of equality or making equal)
If I do this to mine (pour one drink into low wide dish)
Is there still the same amount of orange drink,
Do we have fair shares of orange drink,
Do we have as much orange drink as each other?
Do our shares still look the same?
(Repour drinks into original beakers and repeat questions dividing drink into 2 50ml and then 4 25ml beakers)

1c. Here are two glasses of orange drink (one 100ml beaker $\frac{1}{4}$ full, other $\frac{3}{4}$ full)
Have we the same amount of orange drink, much as as/each other, fair shares?

2a. Here are four balls of plasticine (four same size and shape i.e. of identical appearance approximately $1\frac{1}{2}$" diameter)
There is something inside each ball (two balls with lead equally heavy approximately 150 g, two balls with rice grain equally light, approximately 50 g)
Find and give me the balls which weigh the same, which are as heavy as each other, which are of equal weight. (scale balance available for use)
You have that ball and I have this one (two balls equal in weight as chosen by subject or by experimenter)
Do our balls of plasticine weigh the same?
(After recognition of equality or making equal)
If I do this to mine (flatten one ball into pancake approximately $2\frac{1}{2}$" diameter)
Does mine still weigh the same,
Are our shares of equal weight,
Are our shares as heavy as each other?
Do our shares still look the same?
(Remake two balls and repeat questions cutting plasticine ball into 2 and then 4 pieces)

2b. Here are four balls of plasticine (four same shape, one large approximately $2\frac{1}{2}$" diameter and heavy, approximately 600 g, one small approximately 1" diameter and light, approximately 50 g, one medium approximately $1\frac{3}{4}$" diameter and heavy, approximately 200 g = one small approximately 1" diameter and heavy, approximately 200 g)
There is something inside each ball
Find and give me the balls which weigh the same, which are as heavy as each other, which are of equal weight. (scale balance available for use)

You have that ball and I have this one (two balls equal in weight as chosen by subject or by experimenter)
Do our balls of plasticine weigh the same?
(After recognition of equality or making equal)
If I do this to mine (roll approximately $4\frac{1}{2}$" long and twist one ball)
Does mine still weigh the same,
Are our shares of equal weight,
Are our shares as heavy as each other?
Do our shares still look the same?
(Remake two balls and repeat questions cutting plasticine ball into 2 and then 4 pieces)

2c. Here are two balls of plasticine (one twice as large and heavy as other)
Do they weigh the same, are they as heavy as each other, of equal weight?

3a. Here are four buildings made of wooden blocks (four different buildings made of wooden 1 cm unit cubes, one 4x3x2, one 6x3x2, one 6x3x2, and one 3x3x2)
Find and give me the buildings which have as much room in them as each other, which are the same size, which have equally much space inside them. (unit cube set for measurement available)
You have that building and I have this one (two equal volume 36 unit cube buildings as chosen by subject or by experimenter)
Do our buildings have as much room in them as each other?
(After recognition of equality)
If I do this to mine (make 12x3x1 building out of 6x3x2 building)
Does my building still have as much room in it,
Do our buildings have equally much space,
Are our buildings the same size,
Do our buildings still look the same?
(Remake two buildings 6x3x2 and repeat questions separating one building into two and then four overlapping parts)

3b. Here are four rocks made of metal blocks (four different rocks made of metal 1cm unit cubes, one 5x3x3, one 4x3x3, one 2x3x3, and one 4x3x3)
And here are four dishes of water (four perspex containers 4"x4"x3" exactly alike with water coming up just as far in each)
If I put a rock (4x3x3) in a dish of water what will happen? It will take up room, make the water rise, see? (demonstrate)
Find and give me the rocks which would make the water rise the same, rise equally far, which would take up equally much room in the dishes of water, which would leave as much space as each other for water in the dishes.
You have that rock and I have this one (two rocks of equal volume as chosen by subject or by experimenter)
Would our rocks make the water rise the same, equally far, if put in these dishes?
(After recognition of equality)
If I do this to mine (make 6x6x1 sheet out of 4x3x3 rock)
Would my rock still make the water rise the same, rise equally far,
Would our rocks take up equally much room in the dishes of water,
Would our rocks leave as much space as each other for water in the dishes?
Do our rocks still <u>look</u> the same?
(Remake two rocks 4x3x3 and repeat questions separating one rock into two and then four overlapping pieces)

3c. Here are four balls of plasticine (four same shape, one 4 times as large, and one 2 times as large as two smallest same-volume approximately 1" diameter but different weight balls, the one lead weighted small ball equal in weight approximately 150 g to the largest ball)
And here are four dishes of water (four perspex

containers 4"x4"x3" exactly alike with water coming up just as far in each)

If I put a plasticine ball (approximately 1" diameter) in a dish of water what will happen? It will take up room, make the water rise, see? (demonstrate)

Find and give me the balls which would make the water rise the same, rise equally far, which would take up equally much room in the dishes of water, which would leave as much space for water in the dishes.

You have that ball and I have this one (two balls of equal volume as chosen by subject or by experimenter)

Would our balls of plasticine make the water rise the same, equally far, if put in these dishes?

(After recognition of equality or making equal)

If I do this to mine (turn one ball into a ring approximately 4" in circumference)

Would my share still make the water rise the same, rise equally far,

Would our shares take up equally much room in the dishes of water,

Would our shares leave as much space for water in the dishes?

Do our shares still <u>look</u> the same?

(Remake two balls and repeat questions cutting plasticine ball into 2 and then 4 pieces)

3d. Here are two balls of plasticine (one 4 times as large as the other)

Would they make the water rise the same, take up equally much room, leave as much space for water in the dish?

<u>Post-testing Procedure for Investigation Two.</u>

1. Repeat pre-test 3a except for preliminary choosing of equal objects.

2. Here are two blocks of flats (two buildings made of 36 Lego cubes 1x3x12 high)

Do they have as much room in them as each other?
(After recognition of equality)
If I do this to this one (make one into 1x2x18 high building)
Does it still have as much room in it,
Do the two blocks of flats have equally much space,
Are the two blocks of flats the same size?
Do the two blocks of flats still look the same?
(Remake two buildings 1x3x12 high and repeat questions making one building 1x1x36 high and then 3x12x1 high)

3. Repeat pre-test 3b except for preliminary choosing of equal objects.

4. Here are two submarines (two objects, one made of 36 metal 1cm unit cubes 9x2x2 high, the other made of 18 metal 1cm unit cubes 9x2x1 high)
And here are two bowls of water (two perspex containers 5"x3"x2" exactly alike with water coming up just as far in each)
Would the two submarines make the water rise the same, equally far, if put in these bowls?
(After recognition of inequality)
If I do this to this submarine (make 9x2x2 high into 9x4x1 high submarine)
Would it make the water rise equally far as the other submarine,
Would the two submarines take up equally much room in the bowls of water,
Would the two submarines leave as much space as each other for water in the bowls?
(Remake one 9x2x2 high and repeat questions making other 9x1x2 high and then first one 12x3x1 high)

5. Repeat pre-test 3c except for preliminary choosing of equal objects.

6. Here are two undersea islands (make two discs of plasticine one twice as large approximately $\frac{3}{4}$" thick $2\frac{1}{2}$" across as the other approximately $\frac{3}{4}$" thick

$1\frac{1}{2}$" across but of equal weight 10 grammes)
And here are two bowls of water (two perspex containers 5"x3"x2" exactly alike with water coming up just as far in each)
Would the two undersea islands make the water rise the same, equally far, if put in these bowls?
(After recognition of inequality)
If I do this to this island (squeeze larger island into ball)
Would it make the water rise equally far as the other island,
Would the two islands take up equally much room in the bowls of water,
Would the two islands leave as much space for water in the bowls?
(Remake two discs and repeat questions making one into a cube and then other into a cylinder)

7. Repeat pre-test 1a and 1b and 1c except for preliminary choosing of equal objects.
8. Repeat pre-test 2a and 2b and 2c except for preliminary choosing of equal objects.

Post-testing with Revised Displacement Situations Procedure for Investigation Two.

1. Here are some blocks (4x3x3 high 1cm metal unit cubes) and a dish of water (perspex container 5"x3"x2")
I'll mark where the water comes to
Watch what happens to the water level (pointing) when I put the blocks in the water (demonstrating)
If these blocks were spread along the bottom of the dish
Where would the water level be, where would the water come to?
Would these blocks take up equally much room in the dish of water, leave as much space for water in the dish?
(Repeat for: if the blocks were part at this end, and part at that end of the dish and if the blocks were part in each of these corners)
2. Here is a ball of plasticine (approximately 1"

diameter) and a dish of water (perspex container 5"x3"x2")

I'll mark where the water comes to

Watch what happens to the water level (pointing) when I put the plasticine in the water (demonstrating)

If this plasticine were in a ring on the bottom of the dish

Where would the water level be, where would the water come to?

Would this plasticine take up equally much room in the dish of water, leave as much space for water in the dish?

(Repeat for: if the plasticine were part at this end and part at that end of the dish, and if the plasticine were part in each of these corners).

CHAPTER 4

A FURTHER STUDY OF VOLUME CONSERVATION

I INTRODUCTION

Investigation Three was also concerned with the development of a concept of volume conservation in educationally subnormal children. It was carried out to study the effect of (a) different displacement volume situations on children's responses in the pre-test and (b) different teaching schemes.

Different displacement situations were presented in order to reveal whether and how the way in which the conservation problem was presented influenced the children's recognition of conservation, a point of very general importance. It was likewise hoped to clarify why, in the prior investigation of volume conservation, some children were found to recognise conservation in the displacement but not in the interior volume situations, a reversal of Piaget's interior before displacement volume sequence. In order to explore how differences in the actual presentation of displacement volume problems may influence the recognition of volume conservation, the displacement volume situations and questions described by Piaget, Inhelder, and Szeminska (1960), Piaget and Inhelder (1941), Lunzer (1960d), Lovell & Ogilvie (1961b), Elkind (1961b), and Beard (1962) were considered in detail and in relation to their findings on volume conservation.

It is not clear from the description given by Piaget in <u>The Child's Conception of Geometry</u> whether actual transformations of bricks in the displacement situations were made. Piaget writes (<u>The Child's Conception of Geometry</u>, p.358):

> The child is shown a set of 1cm. metal cubes which are then put at the bottom of a bowl of water. The experimenter builds a block out of 36 units (3x3x4) while the subject notes how the level of the water rises in the bowl. He is then asked if he thinks the level will change if the arrangement of the bricks is modified, by making constructions of 2x1x18 or 2x2x9, etc.

From this description, it is not clear exactly how the conservation problem was presented. If transformations were made with the bricks in the water the children would see the answer, i.e. see that the water level remained unchanged. If transformations were not made it is not clear how the children would understand a 2x1x18 or 2x2x9 arrangement was to be considered. For these reasons, in Investigation Two the actual transformations were made but with the sets of bricks removed from the water. From Piaget's description it is clear that he did not include a second, comparison set of bricks. In this, Piaget's displacement volume situation differed from his interior volume, weight, and substance conservation situations and from his earlier (Piaget and Inhelder (1941)) displacement situation as well as from the displacement situation presented in the writer's prior investigation.

Close examination of the protocols quoted by Piaget (The Child's Conception of Geometry, pp.363, 375-6, 382) in order to discover exactly how the displacement volume problem was presented, does not reveal whether transformations were always carried out but it does appear, from these protocols, though not from the earlier description, that actual transformations were made more often than not. It also appears from these protocols that any transformation made was made with the bricks removed from the water. Flavell (1963, p.340), however, writes that the bricks were transformed while immersed in water. If the latter were the case the children could see and describe the water level.

The displacement situation described by Piaget in Le developpement des quantites physiques chez l'enfant, Chapt3, unlike that described in The Child's Conception of Geometry, included a comparison object as well as an actual transformation in most cases. In the earlier work conservation of volume in displacement situations only was studied and plasticine was used. One piece of plasticine was transformed while the other equivalent piece was left, available for comparison.

In Piaget's investigation (The Child's Conception of Geometry, Chapt. 14) where both interior and displacement volume conservation questions were asked and wooden and metal bricks used, a comparison object was present for the interior but not for the displacement volume problems and Piaget noted the interior before displacement volume sequence. In Investigation Two where both interior and displacement volume conservation questions were also asked, a comparison object was included for both metal bricks and plasticine displacement volume problems as well as for the interior volume conservation problems and no interior before displacement volume sequence was found. It seemed, therefore, that the presence or absence of a comparison object might be a crucial factor influencing the children's responses in the different displacement situations. There were, of course, other differences in the way Piaget's and the present writer's volume conservation problems were presented, for example in the wording of the questions, which might likewise have influenced the children's responses.

Other investigations carried out following Piaget's on the conservation of volume were also considered in detail. Lunzer (1960d), using Piaget's metal unit cube displacement situation, with no comparison object and no actual transformation, found conservation of displacement volume did not appear much before the age of 12 though elementary conservation of amount of room appeared about the age of 7. Lovell & Ogilvie (1961b), using situations and questions quite different from Piaget's and not always including any actual conservation situation or question, concluded that an understanding of interior volume was usually necessary before occupied volume could be understood. They found that interior volume was the least difficult to grasp, followed by occupied volume, and then by displacement volume. Elkind (1961b) presented Piaget's displacement volume conservation problems both with and without actually transforming plasticine objects but always with a comparison object present; he reported that conservation seemed easier to discover by means of a displacement volume problem as opposed to an occupied volume problem. He found that some children more easily recognised conservation when asked whether a ball and sausage would displace the same amount of water than when asked whether they both take up the same amount of space or room. This finding appeared to be contrary to Lovell & Ogilvie's finding that occupied volume was easier to grasp than displacement volume, but the particular situations and questions presented in the two investigations were quite different. In any case, Elkind found that conservation of volume did not appear in most children before the age of 11. Beard (1962), however, using materials quite different from those used in the other volume conservation investigations, with a comparison object always present and transformations sometimes made, found children as young as 7 who answered correctly questions on displacement volume. She, like the present writer, found a wide age range for the acquisition of the concept of volume conservation.

In these four investigations following Piaget's, volume conservation problems were presented in different ways. Lunzer presented both interior and displacement volume problems using unit cubes as Piaget had described in The Child's Conception of Geometry; Elkind presented displacement volume problems only and used plasticine as Piaget had in Le developpement des quantites physiques chez l'enfant; Lovell & Ogilvie presented both interior and displacement volume problems but used situations and materials different from Piaget's; and Beard presented displacement volume problems only but used materials different again from Piaget's and from those of the other investigators. Beard found that conservation in a displacement volume situation was recognised earlier than the other investigators had reported. Elkind and Lovell & Ogilvie did not find the same order in the recognition of occupied and displacement volume conservation. Such differences in the findings on volume conservation may be due to the differences in the ways the conservation problems were presented. There were many differences between the volume situations presented and it is not clear exactly what may have made a difference in the difficulty of the situations. The presence or absence of a comparison object, however, did not seem to be the sole determinant of difficulty; Elkind with a comparison object, like Lunzer without one, found children did not generally recognise displacement volume conservation before the age of 11. The particular question asked as well as the particular displacement situation presented probably influenced the recognition of volume conservation; Elkind found the question of displacement of water was easier for children than the question of taking up space and Beard who found conservation of displacement volume in younger children, asked all her displacement volume questions in terms of water level rather than space taken up. Other factors, for example different criteria for the recognition of conservation, may also have influenced the reported results. Whatever determines the difference in difficulty, the importance of the particular way in which volume conservation problems are presented seems clear. If an interior before displacement volume sequence is being considered, therefore, it would seem that the conservation problems need to have been presented in a similar way, for example, a comparison object and actual transformation need to have been included in both situations if they are included in one.

Different teaching schemes were designed in order to discover: first, whether an understanding of volume conservation can be developed using a simplified method and group teaching; second, what experiences are of most importance in the development of a concept of volume conservation; and third, how prior conceptual development and experience interact. A simplified but still diversified teaching method was tried out with children in a group situation. Then systematic reductions in the teaching were made in the hope of clarifying what were the most effective experiences. Total and partial nonconservers were allocated to the different teaching schemes so as to reveal whether and how initial understanding influences responses to the different teaching experiences.

When the reduced teaching schemes were designed, it was recognised that conservation of volume is not fully explained by either identity, or reversibility, or compensation reasons. The fact of identity does not necessitate volume conservation, for example in the case of water, ice and steam. The possibility of reversibility does not necessarily mean there is no change in volume either, for example a flattened plastic cup has less interior volume though it can be opened out again. And a recognition of compensatory relationships need not involve conceptual rather than perceptual judgments. Conservation of volume, however, as it applies in the unit cube and plasticine situations presented to the children, can be supported by identity, reversibility or compensation reasons. It may be that a distinction between appearance and reality facilitated by these reasons is the crucial factor, but even so the relative effectiveness of identity, reversibility, and compensation reasons has importance.

A simple measure of volume was included where compensation reasons were given in order to provide an objective standard as a basis for conservation judgments. The recording of water levels was introduced to develop freedom from purely perceptual judgment; the separation of appearance and reality with the provision of an external criterion was meant to enable independent conceptual judgment. The use of such an elementary measure for qualitative comparison involved no iteration or addition of standard units, nor prior conservation or transitivity.

As in the prior investigation of understanding of volume conservation, the teaching in this investigation was designed to advance children a certain way in their understanding of volume. The concept of volume conservation taught was seen to be an essential step in the development of a fuller understanding of volume. Again, no exceptions to volume conservation were introduced as these would only confuse E.S.N. children. Interior, occupied, and displacement volumes were considered, as before, in the two conservation situations; the invariance of volume despite changes in shape was here taught using several different methods. The same criterion for an understanding of volume conservation was used as in the prior investigation: a recognition of conservation in all the interior and displacement volume situations presented.

II PROCEDURE AND RESULTS

Fifty-four educationally subnormal schoolchildren aged between 8 and 15 with IQs between 42 and 79 were given a revised form of the Investigation Two pre-test for conservation of substance, weight and volume. This revision included different displacement volume situations. Twenty-six children who gave nonconservation judgments on <u>all</u> the <u>volume</u> questions were selected to be given systematically varied teaching schemes. Chronological age, IQ, and total as against partial nonconservation (i.e. nonconservation of substance, weight and volume as against nonconservation of weight and volume or nonconservation of volume alone) were considered when children were chosen for the different teaching schemes; control subjects were not thought to be necessary as no spontaneous development of conservation had been found in E.S.N. children during the course of previous experiments of similar duration. The children taught were aged between 8 and 15 with IQs between 42 and 76. All twenty-six children taught were twice post-tested with a post-test similar to that used in Investigation Two. Five months later, the twenty-six children were again post-tested.

The materials used were: plasticine, orange drink, two 100ml beakers, one low wide dish, two 50ml beakers, four 25ml beakers, lead weights, rice, wooden 1cm unit cubes, metal 1cm unit cubes, two perspex boxes 5"x3"x2", water, marking pen.

Throughout this investigation the experimenter again tried to avoid giving any extraneous or inadvertent cues by gesture, expression, or tone of voice. Again the situations and questions were presented so as not to bias the children's responses. The procedure was standard yet flexible. Care was taken that children understood the questions as they were intended. Every effort was made to keep the varied teaching schemes the same except for the variables being systematically altered.

(i) Pre-testing.

As in Investigation Two, the pre-test included questions on conservation of substance, weight, and volume in order to select for teaching children with different degrees of understanding of conservation i.e. total nonconservers, nonconservers of volume and weight, and nonconservers of volume only. Besides finding children with no concept of conservation of volume who might be taught that concept, the pre-test was designed to provide a record of the presence or absence of conservation for substance and weight as well as volume prior to the teaching in order to enable the later investigation of generalisation of taught conservation. Likewise the pre-test was meant to reveal any naturally occurring sequence in the development of conservation concepts in E.S.N. children.

In this, as in the prior experiment, care was taken that children distinguished volume from weight from substance and gave judgments about the different attributes for appropriate reasons. The pre-test situations and questions were different for different attributes and, where possible, judgments for different attributes were made mutually exclusive, e.g. volume was separated from weight by differentially weighting same-volume balls of plasticine or by identically weighting different-volume balls of plasticine.

Piaget's conservation problems were again presented. In presenting conservation of substance problems, orange drink as well as plasticine was used. For volume problems both blocks and plasticine were used and interior and displacement volume situations presented. Different materials and situations were introduced where in previous studies they had been found to give rise to different results, e.g. conservation had been found for liquid before plasticine substance, for discontinuous before continuous material, for interior before displacement volume.

Again as in the prior investigation, judgments of inequality were required to expose any answering of 'the same' for any and every situation. Recognition of perceptual differences was also required to test the soundness of any judgments of sameness. A large number of blocks was used wherever an object was made of discontinuous material in order to discourage counting and to separate conservation for volume from conservation for number only.

Throughout this pre-test, as throughout the prior one, the experimenter made all the transformations in full view of the children; children did not manipulate the materials but could see them being returned to their original forms. After each child made a judgment the experimenter made only non-committal remarks and encouraged the child to explain why he thought what he did.

Each child was seen alone for about twenty minutes and sat opposite the experimenter at a small table in a quiet room of the school. A record was kept of each child's responses to the pre-test situations and questions, and his expressed reasons for making those responses.

Again, the criterion for total nonconservation was a failure to recognise equality in any attribute after transformation in shape in every one of the pre-test transformations while also giving a clear indication of which portion was considered greater and for what reason. The criterion for partial nonconservation was nonconservation of one or two of the three attributes, nonconservation in every situation involving a particular attribute or attributes but conservation in some other attribute situations.

The failure to recognise conservation could be exhibited in various ways, the original or the transformed portions could be judged greater and not necessarily in any consistent manner. Conservation judgments could be supported in various ways, identity of material, amount, or weight and/or reversibility could be cited. In cases both of nonconservation and conservation children's explanations of their judgments were taken as evidence of their understanding.

As has been indicated above, the pre-test in this investigation was basically similar to that in the prior investigation of conservation in volume situations. However several changes were made. To begin with, the preliminary choice of two objects equal on a particular attribute was omitted, because a child's understanding could be clarified without thus using up his attention and lengthening the pre-test. Two, rather than three, wordings of each conservation question were made; this was sufficient to eliminate misunderstanding. Certain expressions or words which had led to confusion in the prior pre-testing were omitted. For example, in the substance conservation questions "As much... as" had been understood by some E.S.N. children to imply, and certainly <u>not</u> to exclude, "more", i.e. "as much ... as" questions were often not understood to mean the same as "same amount" "fair shares" questions. Similarly in questions of weight conservation, "as heavy ... as" was misunderstood by some of the children i.e. they did not interpret it as meaning "of equal weight" "weigh the same as", but rather took the question as referring to heaviness in an absolute concrete sense (heavy as opposed to light), not in a relative abstract sense (heaviness as equivalent to weight). In the interior volume situations the word "size" had been ambiguous, i.e. to some children "size" did not mean the same as "room in" "space inside". Because these particular expressions obscured rather than clarified the conservation questions for the E.S.N. children, they were not used in the revised pre-test; this reduced the number of questions in the pre-test. No balance scale nor unit cubes for measuring were provided in this pre-test as no E.S.N. child had ever used them when they were available in the prior investigation.

The aforementioned were some of the changes made in revising the pre-test but the main change was in the displacement volume situations. The displacement situations in this experiment were presented in the following way. No actual transformations were made and no comparison objects were present. The objects were put in the water and the children were asked about the water level and the space taken up if certain transformations were made. The displacement situations thus differed from those in the prior pre-test where transformations were actually made, comparison objects present, and the objects not in water at the time of transformation. The conservation situations in the revised pre-test were no longer consistent with the conservation of weight and substance situations but they were more like the displacement volume situations described by Piaget than were the displacement situations in the prior experiment. Though different in these three main ways, the revised pre-test displacement situations and the original ones were similar in other ways, i.e. similar materials were used and similar questions asked. Discontinuous material was again used in both the displacement and interior volume situations to ensure that any difference in difficulty would be due to the type of volume considered rather than to the fact that discontinuous material is generally conserved before continuous. Care was taken that the children understood that the questions of water level after an object was transformed referred to where it would be in relation to where it was at present with the object already in the water and with the experimenter's hands out of the water in both cases. Care was likewise taken that the children knew that the blocks and plasticine in all the transformations would be entirely covered by the water and on the bottom of the dish.

Where a child was found to recognise conservation in the interior volume situations but not in the revised displacement volume situations, he was asked to make judgments in the original displacement volume situations as well.

The reason a different displacement volume situation was introduced in this second investigation of conservation of volume was to clarify the finding of conservation of displacement volume before interior volume in the prior investigation which was unlike Piaget's finding of conservation in interior volume situations before conservation in displacement volume situations. In the prior investigation, seven children were found who gave conservation judgments in the displacement volume situations but not in the interior volume situations and only one child was found who gave conservation judgments in the interior volume situations but not the displacement volume situations. (All the other children pre-tested in the prior investigation gave the same, i.e. conservation <u>or</u> nonconservation, answers throughout both the interior and displacement volume situations.) It was thought that differences in the displacement volume situations might be the reason for the results differing from Piaget's and this was therefore investigated.

(The details of the pre-testing procedure are given in the chapter appendix).

Fifty-four educationally subnormal children, some from each class in the school, were pre-tested. Of these, nineteen were total nonconservers, two were nonconservers of weight and volume, two were nonconservers of weight and displacement volume, ten were nonconservers of volume only, seven gave conservation judgments in all except the displacement volume situations, one gave conservation judgments in all except the interior volume situations and thirteen recognised conservation in all the pre-test situations.

The thirteen children who recognised conservation in all the pre-test situations ranged in age from 9 to 15 and in IQ from 56 to 79. The nineteen total nonconservers ranged in age from 8 to 15 and in IQ from 49 to 76, the two nonconservers of weight and volume were 10 and 12 years old with IQs of 68 and 77 respectively, and the ten nonconservers of volume only were aged 10 to 15 and had IQs between 42 and 75. The lowest mental age to be found among children who recognised conservation in every pre-test situation was 7.4 (CA 10). The highest mental age to be found among total nonconservers was 8.6 (CA12).

Although the number of children was smaller, the general pattern of the pre-test results was similar to that of the prior investigation. The proportion of children giving nonconservation judgments in all situations, in the weight and volume situations, in volume situations only or giving conservation judgments in all situations was similar to that in the earlier experiment and the age and IQ ranges of these different groups of total/partial nonconservers/conservers was likewise similar. The sequence conservation of substance before weight before volume was again generally found to hold. Except in two cases, where two children recognised conservation for interior volume before weight, conservation was not recognised in any volume situation before conservation of weight was recognised; no children gave conservation judgments for weight or volume before substance. Thus in the majority of cases, again, conservation was found in the generally recognised sequence but this was not without exception.

Nine children in this experiment gave conservation judgments for interior volume but did not recognise conservation in the revised displacement volume situations. This finding was similar to Piaget's (The Child's Conception of Geometry, Chapt. 14) and unlike that of the prior investigation. These nine children failed to recognise conservation in the revised displacement volume situations but immediately afterwards recognised conservation in the original displacement volume situations. The different displacement situations evoked clearly different responses.

Seven of these nine children gave conservation judgments in all the pre-test situations except the revised displacement volume situations and two gave conservation judgments in all but the weight and revised displacement volume situations. Five of the nine children said the water would go up if the proposed transformations were made, three said the water would go down and one said the water would go up or down. The direction of the change in water level was not spontaneously suggested by the children, rather it was usually hesitantly given, that is, the children did not have any firm views on whether the water level would go up or down although they were certain that it would change. Four children could give no reasons for their statements that the water level would not be the same. Of the other five, one boy suggested the water would go up "because it would be pushed up", another boy that the water would rise up "because the air would make it rise", and another that the water would go up "because it's light". Another of the five said the water would go down "because there wouldn't be as much (plasticine or blocks) in it" and still another boy said it would go down "because it (block transformation) would be smaller" and up "because it would be wider."

Although these nine children did not recognise conservation in the revised displacement volume situations, they gave clear conservation judgments and supporting reasons in the original displacement situations as well as in the interior volume situations. Three children gave reversibility-type reasons: two stated that the object was the same before and the third that it would go back the same. Three children gave identity-type reasons: one pointed out that nothing had been taken away and the other two that it was the same amount of material. And three children gave both reversibility and identity reasons.

In order to further clarify and confirm the findings, the pre-test was repeated with these nine children and the results were the same. The children still did not recognise conservation in the revised displacement volume situations though they gave conservation answers with reasons in all the other pre-test situations including the original displacement volume situations.

The wording of the questions in the two displacement situations was as similar as was possible; the questions could not be identically expressed because of the physical differences in the two situations. In one case no actual transformation was made, rather it was described in words; whereas in the other case the transformation was enacted rather than described in full. Though not identical, the questions were basically the same. When certain expressions were deliberately altered, e.g. "if these were - - - " was changed to "if I - - - to these", the children's responses were just the same. Care had again been taken and it was clear that the children realised the questions in the revised displacement situations referred to the present blocks or plasticine and the present water level with the object immersed and no hands in the water. Likewise it was clear that the children realised the object would still be at the bottom of the dish fully covered with water after transformation and that no water would have been lost. The failure to recognise conservation was not due to some obvious misunderstanding of the situations nor to ambiguity of the questions. The children had genuine difficulty in recognising conservation in the revised displacement volume situations whereas they did not have this difficulty in the original displacement situations.

One child can be quoted to illustrate the problem. When asked in the revised displacement volume situations "If this plasticine were - - - would the water level be the same as now?" he answered "no" and "the water would go down" but when asked in the original displacement volume situations "If I do this, would they still make the water level rise the same" he answered "yes" and "because there's the same amount of plasticine". The same transformations were referred to but in the first case they were described verbally whereas in the second case they were demonstrated.

To try to clarify why children recognise conservation in interior volume situations and one type of displacement volume situations but not in another, the nine children were asked questions on interior volume in the revised displacement situation and likewise asked to draw a line where they thought the water would come to after being asked questions on displacement volume. The procedure was this. First, in the original displacement volume situation, after one 4x3x3 building was made 6x6x1, the children were asked to mark where the water level would be for each building andwhether the buildings would have the same room inside them, and whether the blocks would take up the same amount of space. Then, in the revised displacement volume situation, the children were asked to mark where the water level would be if these same blocks were spread along the bottom of the dish, and whether there would be the same room inside the block building and whether the blocks would take up the same amount of space and then again to mark where the water level would be. In the first, the original displacement volume situations all nine children gave conservation answers with reasons to all three questions. In the second, two children gave conservation answers with reasons to all the questions; with the third presentation and juxtaposition of the displacement volume situations, two children began to recognise conservation in the revised displacement situations as well. In the second displacement volume situations, the other seven children still thought the water level would not be the same after the blocks were spread; four of these seven drew a mark above the present water level with the blocks in the water and the three others drew a mark below the present water level. Though certain the water level would not be the same, these seven children were unsure as to whether it would be higher or lower. These same children, then, gave conservation answers to both of the next questions, i.e. they recognised conservation when asked about the amount of space taken up as well as the room inside. When asked again about the water level immediately after giving conservation answers for space taken up they still did not think the water level would be the same. Again the children had great difficulty in explaining why they thought the water level would not be the same; they clearly did not understand the displacement.

The greater separation of the question of water level from that of taking up space revealed that these seven children understood the conservation of space taken up but not the displacement of water. When in the revised displacement volume situations the questions of water level immediately preceded the questions of taking up space, these children hesitated in answering the second question. Until the two questions were asked further apart, the children's problem was not clear; when the question of conservation of interior volume separated the question of water level from that of space taken up, the seven children acknowledged conservation of space taken up in the revised displacement situation too although they thought the water level would not be the same. Thus, seven children gave conservation answers to all the questions asked in the original displacement situation with the concrete comparison object and actual transformation; in the revised displacement situation with no comparison object nor actual transformation, they gave conservation answers to questions of amount of room inside or amount of room taken up but did not recognise that the water level would be the same.

The difference between these children's recognition of conservation of space taken up and their failure to realise the water level would be the same was not the result of a simple misunderstanding of what was being considered. These children understood the distinction between the question of room inside and amount of space taken up. Their conservation responses to the question of space taken up were not the result of the juxtaposition with the room inside question nor a practice effect; when asked immediately afterwards they did not recognise the water level would be the same. The reasons the children gave for their recognition of conservation of space taken up included the fact that it could be made back again and that it was the same blocks, and none had been taken away. (One practice effect was found in this investigation. The one child who gave non-conservation judgments for interior volume but conservation judgments for displacement volume was found, on the repetition of the pre-test, to recognise conservation for interior volume as well.)

In summary, children were found to give different judgments in different displacement volume situations, i.e. children were found to recognise that the transformed object would make the water come to the same place and to give reasons for conservation when the problem was presented with the transformation actually made, though not in water, and comparison object present, yet the same children did not recognise the water would come to the same place when the problem was presented with no actual transformation made nor comparison object present though the object actually was in water. These children did not exhibit any awareness of the inconsistency in their responses. Likewise, they showed no awareness of the contradiction when in the same displacement volume situations they gave conservation judgments for space taken up but did not recognise the water level would be the same. In one type of displacement volume situation the children revealed their understanding of conservation and recognised the water level would be the same; in another type of displacement volume situation the same children, though they recognised conservation of space taken up, did not recognise the water level would be the same. The influence of the particular situation was evident. Conservation was again shown not to be an all or none development; it was recognised in some but not necessarily in all situations.

(ii) Teaching.

Twenty-six children who showed no concept of conservation in the interior or displacement volume situations were selected to be given different teaching experiences designed to further the development of this concept. No control subjects were included in this investigation because in all of the experimenter's previous investigations of similar duration with E.S.N. children no spontaneous development of conservation concepts was found.

Five different teaching schemes were devised and the children accordingly divided for different teaching. The first teaching scheme, a revised version of the method the experimenter used to teach a concept of volume conservation in a prior investigation, involved a combination of: counting discontinuous material to emphasise identity in the interior volume situation, measuring displacement in the displacement volume situation using blocks, manipulating reversibility in the displacement volume situation using plasticine, and verbalising reasons of identity, compensation and reversibility as well as empirical findings. In the second teaching scheme one of the three experiences, counting for identity or measuring displacement or manipulating reversibility, was omitted and verbalisation of only two reasons for conservation, rather than three reasons, was included. The third teaching scheme involved demonstrations by the experimenter and verbalisations by both the experimenter and the children; the children watched the experimenter counting to emphasise identity, measuring displacement, and manipulating reversibility and they verbalised the identity, the compensation, and the reversibility reasons for conservation. The children did not manipulate the materials. One less volume situation was included; the displacement situation using blocks was omitted. Further, the revised displacement situation was presented where in the other four teaching schemes the original displacement situation was presented. The fourth teaching scheme provided one experience only, either counting for identity or measuring displacement or manipulating reversibility, and verbalisation of one appropriate reason for conservation. Two volume situations only were presented; the displacement volume situation using plasticine was omitted. In the fifth teaching scheme, verbalisation of a single reason only was included and no manipulations nor demonstrations were made. Thus, in the different teaching schemes different amounts of experience were given. The first teaching scheme included a variety of experiences which had been found to foster a concept of volume conservation in the prior investigation with E.S.N. children. In the other four teaching schemes the amount of experience was progressively reduced from the second to the fifth teaching scheme.

Six children were chosen for the first teaching scheme, six for the second, four for the third, six for the fourth, and four children for the fifth teaching scheme. The children less likely to learn, generally the younger and lower IQ total nonconservers, were given the fuller teaching while the children more likely to learn, generally the older and higher IQ partial conservers, were given the more abbreviated teaching. This was done in order to ensure that any differences in degree of learning would be due to the omission of teaching experiences and not just to differences in the children's prior conceptual development.

All the teaching schemes were similar in so far as they all were concerned with physical and not mathematical volume and with conservation in the interior and the displacement volume situations. The pre-test situations were repeated in every teaching scheme, as they had been in the prior investigation, and each teaching scheme was standard but adapted to the children. All the children were taught in a room adjoinin a classroom that was in use at the same time, i.e. the children were taught under classroom conditions. These were the basic similarities between the teaching schemes which then differed in the amount and type of manipulations of concrete materials and verbalisations of reasons. The teaching schemes differed also in the time required to implement them; ten to twenty minutes was the time range for the different schemes. Group and individual teaching was used in this investigation. A group of four children was taught using the first scheme and another group of four children was taught using the third scheme; the rest of the children were taught individually.

Details of the children selected for the different teaching schemes follow :

	Name:	C A y	m	IQ	Nonconservn. total	part.	Group	Indiv.
First scheme	Elizabeth C.	10	9	59	x		x	
	Jane E.	10	8	76	x		x	
	Nicholas L.	11	3	75	x		x	
	John R.	11	5	57	x		x	
	Paul B.	9	2	65	x			x
	Ruth L.	8	8	65	x			x
Second scheme	James B.	9	11	64	x			x
	Beverley S.	9	11	68		x		x
	Beverley G.	10	6	67	x			x
	Alan D.	10	6	75		x		x
	Nigel M.	10	6	65	x			x
	Patrick T.	12	-	77		x		x
Third scheme	Graham B.	12	4	69	x		x	
	Rosemary P.	12	7	59	x		x	
	David S.	12	5	62	x		x	
	Trevor S.	12	3	60	x		x	

	Name	C A		IQ	Nonconservn. total/part.		Group/Indiv.	
		y	m		total	part	Group	Indiv.
Fourth scheme	Hamish F.	15	4	57	x			x
	John R.	15	2	42		x		x
	Brian M.	14	3	49	x			x
	Keith B.	11	10	74		x		x
	Jeanette P.	12	8	57	x			x
	David O.	11	-	74		x		x
Fifth scheme	Robert B.	11	2	64		x		x
	Janet M.	11	6	72		x		x
	Sheila F.	12	7	61		x		x
	Brian H.	11	8	73		x		x

First teaching scheme:

Four of the six children, all total nonconservers, chosen for the first, the fullest, teaching scheme were taught as a group. Two boys and two girls of similar chronological age, two of lower and two of higher IQ were taught. They sat with the experimenter around a table in the centre of which were put the materials for the teaching. These children answered individually and as a group throughout the teaching session and their responses were recorded at each stage of the teaching. The full but revised teaching method began with a consideration of interior volume. Two 6x3x2 high wooden-block buildings were presented and recognised as equal on room or space inside. Then one of the buildings was made 12x3x1 high and the pre-test questions for interior volume were asked. This was followed by the experimenter's counting the same number of blocks in each building emphasising the identity of the material and that nothing had been added or taken away. Reversibility was not manipulated in this situation but it was mentioned in explaining conservation as was compensation. The same demonstration and explanation of the identity basic to the conservation of interior volume was repeated for the second and third transformations of the 6x3x2 wooden-block buildings, i.e. for the separation of one building into two and then four overlapping parts, but the children were encouraged to do the explaining rather than just listening to the experimenter. The teaching continued with a consideration of displacement volume. After an initial demonstration of displacement, i.e. after thirty-six metal blocks were immersed in a dish of water and the water rise recorded, two 4x3x3 high metal-block rocks were presented and recognised as equal in displacing water or taking up room. Then one of the rocks was made 6x6x1 high and the pre-test questions for displacement volume were asked. After this, the displacement of water by both the 4x3x3 and the 6x6x1 rocks was measured, i.e. the water level was marked on the dish by the experimenter, in order to provide evidence of conservation; and compensation, i.e. that one rock was wider but the other higher, was pointed out by the experimenter. Identity and reversibility were likewise pointed out. The same demonstration of conservation in the displacement volume situation and pointing out of compensation relations was repeated for the second and third transformations of the 4x3x3 metal-block rocks, i.e. for the separation of one rock into two and then four overlapping parts, and the children were encouraged to express the evidence for conservation. The teaching ended with a further consideration of displacement volume using plasticine instead of blocks. After an initial demonstration of displacement of water by plasticine, two identical in volume though not in weight plasticine balls were presented and recognised as equal in displacing water or taking up room. Then one of the balls was made into a ring and the pre-test questions for displacement volume were again asked. Both the experimenter and the children subsequently manipulated reversibility and stated that the material could be made back into the same shape as it was before. The experimenter again pointed out the identity of the material, that nothing had been added or taken away. Similar manipulation and verbalisation of reversibility as evidence for conservation was repeated for the second and third transformations of the plasticine i.e. for the cutting of one plasticine ball into two and then four pieces.

Thus, in the revised full teaching scheme the children were given varied experiences basic to the development of a concept of volume conservation. Three demonstrations or manipulations associated with three reasons for conservation were performed in three volume situations. One demonstration or manipulation per volume situation was made where in the original teaching method more than one had been made in every volume situation. No containers were introduced in the revised teaching method because the filling of these with counted blocks made unnecessary demands on the children's attention and all the children understood what was meant by interior volume when the wooden block buildings were presented. No child was confused by the fact that questions of room in or space inside were asked of buildings with blocks all through them rather than of empty containers.

All four children in the group gave nonconservation answers for the first transformation in the interior volume situation. Three children still gave nonconservation answers for the second transformation but one child recognised conservation and said that one building was longer but the other was higher so they "balance out". For the third transformation in the interior volume situation only one child failed to recognise conservation; two of the children who recognised conservation gave compensation type reasons and the third child who recognised conservation said that there were the "same many" blocks. In the displacement volume situation involving metal blocks, only one child at first recognised conservation; she pointed out that there were the "same blocks" all the time. Later, all four children recognised conservation in the displacement volume situation and gave identity-type reasons, three said there were the "same blocks" and one that there were the "same many" blocks. Finally, in the displacement volume situation involving plasticine all but one child on the first transformation recognised conservation for reasons of identity and that child, too, later recognised conservation giving an identity-type reason.

The group teaching took approximately twenty minutes; measurement of displacement and manipulation of reversibility held all the children's attention through to the end. Measurement appeared to be particularly convincing for the children. The influence of the group situation was also apparent; the children worded their reasons similarly copying expressions from other children, e.g. "balances out" "same many". Compensation and identity-type reasons were the only ones given by these children. As might be expected, the two children of lower IQ were slower to understand conservation, i.e. did not recognise conservation until the later transformations.

A similar method was used in teaching individually the other two children chosen for the first, the full revised, teaching scheme. These two children, the youngest to be taught conservation in the volume situations, gave nonconservation answers for the first and second transformations in the interior volume situation but recognised conservation for the third transformation. One child said there were the "same blocks"; the other said none had been "taken away". Their reasons for conservation were expressed differently. In the displacement volume situation involving metal blocks, the two children did not recognise conservation for the first transformation but did for the second and third transformations and gave identity-type reasons, that there were the "same blocks" or the "same amount" of blocks. Again in the displacement volume situation involving plasticine, the two children did not recognise conservation for the first transformation. The younger child did not recognise conservation until the third transformation but the older recognised conservation for the second as well as third transformation. Both children gave the reason that it was the same plasticine.

Teaching the children individually took about twenty minutes for each child, the same amount of time as the group teaching took; and the children's attention was again held by the measurement of displacement and the manipulation of reversibility. Identity-type reasons were the only ones given by the children; the younger child repeated that it was the same material while the older child said in the first situation that nothing had been taken away, in the next situation that it was the same amount still, and in the last situation that it was the same material.

Second teaching scheme:

All six of the children, four boys and two girls, chosen for the second teaching scheme were taught individually. Two children, one total nonconserver and one partial nonconserver, were given no experience of counting for identity, two other children, again one total nonconserver and one partial nonconserver, were given no experience of manipulating reversibility (care was taken to exclude any demonstration of reversibility in the course of the teaching), and the third pair of children, one a total nonconserver and one a partial nonconserver, were given no experience of measuring displacement. Each of the three pairs of children experienced and verbalised two reasons for conservation; the first pair of children manipulated reversibility and measured displacement, the second pair counted for identity and measured displacement, and the third pair manipulated reversibility and counted for identity. In other words, a different experience was left out of each of the three teaching methods comprising the second teaching scheme. Apart from the absence of either counting for identity or manipulating reversibility or measuring displacement, the three pairs of children were given similar teaching. The three volume situations and the transformations and questions were the same in every case as t ose of the revised full teaching scheme (see above); the teaching procedure, demonstrations and manipulations and verbalisations, was likewise similar except that particular experiences were systematically left out. In this second teaching scheme, one reason for conservation was demonstrated or manipulated in each volume situation and two reasons verbalised; as there were three volume situations and only two reasons to be included in the teaching, reversibility was manipulated in two situations when counting for identity was omitted, displacement was measured in two situations when manipulating reversibility was omitted, and counting for identity was carried out in two situations when measuring displacement was omitted. The children's responses were recorded at each stage of the teaching.

All six children gave nonconservation answers for the first transformation in the interior volume situation. For the second and third transformations, one pair of children who had been given manipulation of reversibility experience still gave nonconservation answers. For these transformations, a second pair of children who had been given experience of counting for identity recognised conservation. One child, previously a total nonconserver, gave no reasons for her conservation judgments and the other child, previously a partial nonconserver, gave the reason, not included in his teaching, that the building could be put back the same as before. A third pair of children who had been given experience of counting for identity did not recognise conservation for the second transformation but did so for the third transformation. One child, previously a partial nonconserver, gave no reason for his conservation judgments and the other child, previously a total nonconserver, gave the reason that there was still the "same plenty". In the displacement volume situation involving metal blocks, the pair of children who had given nonconservation answers for all the transformations in the interior volume situation again gave nonconservation answers except for the third transformation where both children recognised conservation but gave no reasons for their judgments. The second pair of children who had recognised conservation in the second and third transformations of the interior volume situation recognised conservation in the displacement volume situation. One of these children again gave no reasons for her conservation judgments and the other child gave the reason that no blocks had been taken away. The third pair of children who had recognised conservation only in the third transformation of the interior volume situation recognised conservation in the second as well as the third transformations of the displacement volume situation. One of these children still gave no reasons for his conservation judgments; the other child gave the reason that the rock was the "same size and same heavy". Finally, in the displacement volume situation involving plasticine, the first pair of children still did not recognise conservation: they gave nonconservation judgments for all three transformations. The second pair of children recognised conservation in all the transformations; one child still gave no reasons for her conservation judgments but the other child gave the reason that nothing had been taken away. The third pair of children gave conservation judgments for the third transformation only; one child gave the reason that the plasticine could be made back the same and the other child gave the reason that it was the "same heavy".

The teaching generally took about the same amount of time as the revised full method of teaching did, about twenty minutes for each child. The children did not always give as reasons for conservation the reasons introduced in the teaching; one child who was given no direct experience of reversibility gave reversibility-type reasons as well as identity-type reasons which had been taught, and another child mentioned identity of weight as evidence of conservation in the displacement volume situations though this had not been mentioned in the teaching.

Third teaching scheme:

The four children, all total nonconservers, chosen for the third teaching scheme were taught as a group. Three boys and one girl, close in chronological age and IQ, sat with the experimenter around a table in the centre of which were put the materials for the teaching. The children answered individually and as a group throughout the teaching session and their responses were recorded at each stage of the teaching.

Conservation was demonstrated and explained in two volume situations only, the interior volume situation with wooden block buildings and the displacement volume situation with plasticine. Basically, the teaching method was similar to that of the revised full teaching scheme (see above); the volume situations, the transformations, the questions, the demonstrations and the verbalisations were the same as those of the fuller teaching scheme but the displacement volume situation involving blocks was omitted and a few other changes were made. One important change was that the teaching in the displacement volume situation was different for this group of children from that given in the revised full and in the other three teaching schemes. No comparison object was present, whereas a comparison object was present in all transformations in the other teaching schemes; the water level was measured before and after a single plasticine ball was transformed into a ring. Thus, the displacement volume situation in the third teaching scheme emphasised identity of material and did not entail equivalence. Another change from the earlier teaching schemes was the elimination of any manipulation of the materials by the children; the experimenter and not the children counted for identity and manipulated reversibility in the interior volume situation and then measured displacement and manipulated reversibility in the displacement volume situation. The children as well as the experimenter, however, stated the identity and the reversibility and the compensation reasons for conservation. They also stated the empirical evidence for conservation obtained by measuring displacement.

All four children gave nonconservation answers for the first transformation in the interior volume situation. One child recognised conservation for the second transformation and gave the reason that it was the same blocks. All four children then recognised conservation for the third transformation and gave the same identity-type reason. For the first transformation in the displacement volume situation all four children again gave nonconservation answers. For the second transformation three children gave conservation answers for reasons of identity, i.e. two children said that it was the same plasticine and one child said that nothing had been added or taken away. All four children recognised conservation for the third transformation and gave the same reason, that it was the same plasticine still.

The teaching took about fifteen minutes. The individual children's judgments were influenced by the group though they answered separately at the different stages in the teaching. Identity-type reasons were the only ones the children gave for their conservation judgments but measuring displacement appeared to be a particularly convincing demonstration. None of the children immediately generalised and recognised conservation in the displacement volume situation, but the use of plasticine rather than metal blocks may have lessened the likelihood of this.

Fourth teaching scheme:

All of the six children, five boys and one girl, chosen for the fourth teaching scheme were taught individually. Two children, one a total nonconserver and one a partial nonconserver, were given only manipulation of reversibility experience. Two other children, again one a total and the other a partial nonconserver, were given only counting for identity experience. A third pair of children, one a total and one a partial nonconserver, were given only measuring of displacement experience. Each of the three pairs of children thus experienced and verbalised one reason only for conservation; a different reason was demonstrated by the experimenter for each pair of children and only the one reason was stated by the experimenter and the children. Conservation was demonstrated and explained in two volume situations, the interior volume situation with wooden block buildings and the displacement volume situation with plasticine. The volume situations, the transformations, the questions, the demonstrations, and the verbalisations were similar to those of the revised full teaching scheme (see above) but this fourth teaching scheme was greatly abridged. There was no displacement volume situation involving metal blocks, the experimenter demonstrated and verbalised one reason for conservation only for each pair of children, and the children never manipulated the materials, they just repeated the reason given. The children's responses were recorded at each stage of the teaching.

All six children gave nonconservation answers for the first transformation in the interior volume situation. For the second and third transformations, one child from each pair, the child who had previously been a partial nonconserver recognised conservation. The partial nonconserver who had been given manipulation of reversibility experience gave no reason for his conservation judgments, the one who had been given counting for identity experience gave as his reason for conservation that there were the same blocks, and the one who had been given measuring of displacement experience gave no clear reason for his conservation judgments. The total nonconserver from each pair of children still gave nonconservation answers for the second and thir d transformation in the interior volume situation. In the displacement volume situation all six children gave nonconservation answers for the first transformation. Then, one child from each pair, again the child who had previously been a partial nonconserver, recognised conservation for the second and third transformations. The one partial nonconserver who had been given manipulation of reversibility experience still gave no reason for his conservation judgments, the one who had been given counting for identity experience gave as his reason in this situation that no plasticine had been taken away, and the one who had been given measuring of displacement experience this time gave clear reasons, that there was the same amount and the same heaviness of plasticine. The total nonconserver from each pair of children still did not recognise conservation for the second and third transformations in the displacement volume situation.

The teaching took about ten minutes for each child. Identity-type reasons were again the only reasons given by the children for their conservation judgments; this type of reason was mentioned not only by a child who had been given counting for identity experience but also by a child who had not been given this experience.

Fifth teaching scheme:

The four children, all partial nonconservers quite close in chronological age and IQ, chosen for the fifth teaching scheme were taught individually. Two children, one boy and one girl, were given the same single verbal explanation of conservation for every transformation in the three volume situations: the identity of the material and the fact that nothing had been added or taken away was pointed out to them. Two other children, again one a boy and one a girl, were also given a single verbal explanation of conservation throughout: reversibility and the possibility of returning the material to its original form was pointed out. The three volume situations, the transformations, the questions and the verbal explanations were similar to those of the revised full teaching scheme (see above), but no actual experience of manipulating reversibility or counting for identity or measuring displacement was given. No demonstrations by the experimenter nor manipulations by the children were included in the teaching which consisted solely of the verbalisation of <u>either</u> identity <u>or</u> reversibility reasons by the experimenter. (Compensation reasons were not presented on their own because they do not necessitate more than a perceptual judgment.) The children's responses were recorded at each stage of the teaching, and the teaching took about ten minutes for each child.

All four children gave nonconservation answers throughout the teaching i.e. none of the children recognised conservation for any of the transformations in the volume situations. The merely verbal explanation of identity or reversibility as reasons for volume conservation judgments did not result in a recognition of conservation.

(iii) <u>Post-testing</u>.

The first post-test was given to each child one week after the teaching session, and the second post-test, one week after that. Each child was seen alone for about twenty-five minutes. The standard post-test procedure was similar to that of the pre-test but included some new as well as familiar materials, transformations, and verbal expressions to test whether a broad understanding had been developed rather than a specific response learned. Questions demanding inequality judgments were included to reveal whether there was, for reasons other than that of a genuine concept of conservation, any agreement to sameness after transformation and to test for further generalisation; children were required to give not only simple judgments of inequality but also judgments of conservation of inequality of volume. Throughout the post-test, the children were asked to give reasons for their judgments; both judgments and reasons were recorded for each child. The stability of the children's conservation judgments was tested by the experimenter's pointing out perceptual differences; the children's resistance to counter suggestion was tested. All transformations were made in full view of the children; gestures were used to clarify the questions. Noncommittal remarks only were made after the children's responses.

The actual wording of the post-test was similar to that of the pre-test. The pre-test questions and situations were repeated in the post-test and the questions in the new situations were worded similarly. In the second situation of the post-test, new material, Lego blocks, was introduced, new transformations made, and new verbal labels used but the problem was similar to that in the teaching, i.e. equality was to be recognised after transformation. In the third and fourth situations, the wording of the first question was altered from that in the pre-test in order to avoid giving any suggestion of sameness; otherwise the questions and situations were the same as in the pre-test. In the sixth situation, that involving unequal metal-block transformations, new verbal labels and new transformations, though not new materials, were introduced; the problem, i.e. that of recognising and conserving for inequality, was different from that in the teaching. The eighth situation, the final new situation in the post-test, was again an inequality situation but one involving inequality of volume and equality of weight. No new material was introduced but new transformations and new verbal labels were used. Throughout the rest of the post-test the familiar pre-test situations were presented.

The post-test included both the revised and the original displacement volume situations, as well as interior volume situations; the revised situations were presented before the original to reverse the order in which they were introduced in the post-testing of the prior investigation of volume conservation, where conservation in the revised displacement situations was tested about a month after it had been tested in the original displacement situations.

All twenty-six children taught using the five different teaching schemes were post-tested in exactly the same way. (The details of the post-testing procedure are given in the chapter appendix).

The results of post-testing the children given the different teaching experiences follow. With the exception of one girl, each child gave similar judgments and reasons in both the first and second post-tests.

First teaching scheme:

All six children taught using the full but revised teaching method made conservation judgments in all the post-test situations. The four children taught as a group and the two very young children taught individually recognised conservation throughout their first and second post-tests. They gave conservation judgments on the familiar, unfamiliar, and inequality transformations and generalised their taught concept of conservation to the weight and substance situations too. Identity reasons were given by the six children for all their conservation judgments. The fact of its being the same material or same amount of material was pointed out by five of the children; and the fact that nothing had been taken away was mentioned by one boy, one of the children who had been individually taught. Compensation was the only other reason given and this was mentioned by one girl, one who had been taught in the group. One reason only was generally given by each child throughout the post-tests.

The revised full teaching scheme was shown to be effective for group as well as individual teaching. Children taught as a group developed a broad understanding of conservation just as children taught individually had; neither individual tuition nor an isolated room was essential to the effectiveness of the teaching. The revised full method worked as well as the original full method had. All six children, previously total nonconservers and of low mental age, recognised, generalised and gave reasons for conservation after they had been taught in the revised full teaching situations.

Second teaching scheme:

The six children all individually taught using one of three cut teaching methods improved in their understanding of conservation but not equally nor, in most cases, as much as those children given the fuller teaching scheme. Of the two children taught with counting for identity omitted, one, previously a partial nonconserver, gave no conservation of volume judgments throughout the first post-test but recognised conservation in all but the interior volume situations of the second post-test. For her conservation judgments this child gave identity reasons though these were not included in her teaching. Of this pair, the other child, previously a total nonconserver, recognised and gave reasons for conservation in some situations but not in other situations, i.e. he made conservation judgments in all but the interior volume and a few of the weight and substance situations. He gave reversibility reasons for conservation except in the revised displacement volume situations where reversibility was not enactable. Of the pair of children taught with manipulation of reversibility omitted, one, previously a partial nonconserver, recognised and gave reasons for conservation throughout the post-tests. He gave identity reasons as taught but also reversibility reasons for his conservation judgments. Of this second pair, the other child, previously a total nonconserver, also gave conservation judgments throughout but gave no reasons for them. She recognised conservation in all the weight and substance as well as volume situations. Of the two children taught with measuring displacement and compensation reasons omitted, one, previously a partial nonconserver, recognised and gave reasons for conservation throughout the post-tests. He gave some identity and some reversibility reasons, as taught, for his conservation judgments but these were never clearly expressed. Of this third pair, the other child, previously a total nonconserver, recognised and gave reasons for conservation in some situations but not in other situations, i.e. he made conservation judgments in the displacement volume situations, both revised and original, giving the reason of identity of weight but he did not recognise conservation in the interior volume or weight or substance situations.

The omission of certain experiences and reasons for conservation from the teaching resulted in differences in degree of understanding, i.e. not all children developed a broad concept of conservation when the teaching was cut. The decrease in understanding of conservation with the elimination of one of three key experiences and reasons was evidenced in: the failure of one child to recognise conservation in any of the volume situations of the first post-test, the failure of two other children to generalise conservation to all the weight and substance situations, and the failure of these three children to make conservation judgments in the interior volume situations, of the second as well as first post-test, although they recognised conservation in all the displacement volume situations. The recognition of conservation in the displacement situations after the failure to recognise conservation in the interior volume situations may appear to be a practice effect. Conservation was not recognised in the earlier situations but it was recognised in the later. However, such nonconservation followed by conservation was present in the second as well as first post-test, i.e. nonconservation judgments were made after conservation had been recognised in earlier situations, and, likewise, conservation was not always recognised in the weight and substance situations which followed the displacement volume situations where conservation judgments were made.

The relative importance of the different experiences and reasons in the development of a concept of conservation was not clear. Although manipulation of reversibility appeared to be less essential, in that two children learned to recognise conservation in every post-test situation without being given the reversibility training, the small number of children given the different teaching experiences and reasons and their individual differences, including particularly differences in their prior understanding of conservation, meant that no clear answer was found to the question of the particular elements essential to the development of a broad understanding of conservation.

Third teaching scheme:

The four children taught as a group using another cut teaching method also improved in their understanding of conservation but again not equally, nor, in two cases, as much as children given the full teaching scheme. Two children, one girl and one boy, recognised conservation in all the first and second post-test situations and gave clear reasons for their judgments. The girl gave only identity of material reasons throughout but the boy gave several reasons, identity, reversibility, and compensation reasons, for his conservation judgments. The two other children recognised and gave reasons for conservation in some situations but not in other situations. One boy made conservation judgments in all but certain initial transformations: in the interior volume situations, in the displacement volume situations using blocks, and in the weight situations. He gave identity-type reasons for his conservation judgments, i.e. he pointed out that nothing had been added or taken away or that the weight was the same. The other boy recognised conservation for all the familiar materials but did not give conservation judgments when new materials were introduced. He too gave clear identity-type reasons for his conservation judgments, i.e. he too pointed out that nothing had been added or taken away and that it was the same material and weight. All four children recognised conservation as easily in the original as in the revised displacement volume situations which had been the ones presented in their teaching.

All four of the children, previously total nonconservers, generalised and recognised conservation in at least some of the weight and substance situations. Two children recognised conservation in all the weight and substance as well as volume situations, one recognised conservation of weight and substance in all but the first weight transformation and one recognised conservation of weight and substance except in the liquid substance situation. The reasons the children gave for conservation in the weight and substance situations were similar to those they had given for volume conservation. Identity reasons were the most frequently given reasons throughout the post-tests; they were mentioned by all four children. Reversibility and compensation reasons were mentioned by one boy only.

Although all four children improved in recognising conservation, there were clear individual differences in degree of understanding as a result of the cut teaching. The elimination of one of the three volume situations and/or the less concrete displacement situation experience and/or the absence of manipulation meant that not all the children developed a broad concept of conservation although they were all taught together.

Again no answer was found to the question of what in particular is essential to the development of a broad understanding of conservation, though clearly, the change in the number and/or type of volume situations presented, like the change in the number and/or type of conservation experiences and reasons presented in the prior teaching scheme, influenced the degree of understanding of conservation.

Fourth teaching scheme:

Of the six children individually taught using one of three further reduced teaching methods, three improved in their understanding of conservation but the other three did not. None of the three children who previously had been total nonconservers recognised conservation in any of the first and second post-test situations; neither counting for identity alone nor manipulating reversibility alone nor measuring displacement and verbalising compensation reasons alone, in two volume situations, gave these children sufficient experience and reason for the development of a concept of conservation. Of the three children, previously partial nonconservers, who improved in their understanding of conservation, two recognised and gave reasons for conservation in all of the first and second post-test situations. One boy gave identity-type reasons only, as he had been taught; he said, for example, "you haven't pulled any off, it's the same still". The other boy also gave identity-type reasons only, though these had not been included in his teaching; he pointed out "it's still the same amount" though he had been given measuring displacement experiences and compensation reasons in his teaching. The third previous partial nonconserver, a child about four years older than the other two partial nonconservers but of much lower IQ (42 as against 74), recognised conservation in all but the interior volume situations of the two post-tests; he gave no clear reasons for conservation in the displacement volume situations though reversibility reasons had been emphasised in his teaching.

The inclusion, for each child under this teaching scheme, of only one of the three main experiences and reasons for conservation given in the full teaching scheme, resulted in only two of the six children developing a broad concept of conservation. The relative importance of the different experiences and reasons in the development of understanding of conservation was, again, not clear. When given either identity or reversibility or measuring and compensation training the total nonconserver in each pair of children did not learn to recognise conservation whereas the partial nonconserver did. In other words, the particular child's prior understanding of conservation, more than the particular teaching experience and reason, determined whether the child learned to recognise conservation. While no clear answer was found to the question of essential elements in the development of a broad understanding of conservation, it was found that experience of more than a single reason for conservation is important if all children, total as well as partial nonconservers, are to benefit from the teaching.

Fifth teaching scheme:

Of the four children, all previously partial nonconservers, individually taught using one of two very cut, almost purely verbal teaching methods, two children developed no understanding of volume conservation, i.e. they failed to recognise conservation of volume in all the first and second post-test situations, and two other children gave conservation of volume judgments in only one or two of the post-test situations, i.e. one recognised conservation in one displacement volume situation and the other in the first interior volume transformation and one later displacement volume transformation. The boy who recognised conservation in one displacement volume situation, the original and not the revised displacement situation involving plasticine, gave identity-type reasons as he had been taught. The girl who recognised conservation for a couple of transformations in the interior and displacement volume situations gave reversibility type reasons as she had been taught.

Verbalisation alone of identity or reversibility reasons in the three volume situations was not sufficient for the development of a broad concept of conservation; neither identity nor reversibility reasons alone when merely verbally expressed were enough to develop a clear understanding of conservation in these children. Even here, however, there were individual differences in the extent to which different children benefitted from the teaching. The development of a concept of conservation again did not appear to be an all or none affair.

(iv) Follow-up Study.

In the follow-up study, carried out five months later, the twenty-five children still at the school were again given the post-test for volume, wei ht, and substance conservation and in exactly the same conditions as before. (See chapter appendix for details.) Twenty of these children responded exactly as they had in the previous post-tests; five children gave answers different from those they had given previously.

Six of the original twenty-six children had been given the first, the fullest teaching scheme. Of these the five still available for the follow-up study recognised and gave appropriate reasons for conservation in every situation presented. Each child gave the same reasons as he had given before. The durability of the concept of conservation developed was evident. Of the six children given the second teaching scheme, four responded exactly as they had before (i.e. three still recognised conservation throughout while the fourth recognised conservation in the displacement volume situations only) but two responded differently (i.e. one partial conserver recognised and gave reasons for conservation in one more situation, three more transformations, than he had before while another partial conserver reverted to the non-conservation judgments she had given in her first post-test not maintaining the improvement evidenced in her second). The four children given the third teaching scheme now all recognised and gave reasons for conservation in all the post-test situations (i.e. two responded exactly the same as before while two partial conservers improved in recognising conservation); each gave the same reasons for conservation judgments as he had before. Of the six children given the fourth teaching scheme, five responded the same as on the previous post-tests (i.e. the three total nonconservers remained total nonconservers and the two total conservers remained conservers throughout) and one improved (i.e. one partial conserver recognised and gave reasons for conservation in one more situation, three more transformations, than he had before). The four children given the fifth teaching scheme all responded the same as they had on the earlier post-tests (i.e. all four still did not recognise conservation in any volume situations).

Thus the follow-up study showed several things. A lasting understanding of conservation was developed using the revised full teaching scheme, taught conservers remained conservers. Children who, given abbreviated teaching, did not learn to recognise conservation remained nonconservers over the five months as did untaught nonconservers in other investigations. Several, though not all, children who became partial conservers, after abbreviated teaching, developed further understanding of conservation during the five months; four partial conservers improved in recognising conservation and only one regressed. In summary, after teaching, neither total conservers nor total nonconservers changed over time but five out of six children who became partial conservers did change over the five months.

III DISCUSSION

This investigation of the development of understanding of conservation clarified questions raised in the prior investigation of volume conservation. In the pre-testing of this investigation, the effect of different displacement situations was revealed. Teaching and post-testing indicated the need for varied experiences, reasons, and situations; a simplified but still fairly full teaching method was found to be effective in group as well as individual teaching but shorter teaching methods were found to be less effective. The question of essential elements remained unanswered.

The results in the pre-testing of this investigation provided some clarification of the question of order in the development of interior and displacement volume conservation. Whereas in the prior investigation of volume conservation some children were found to recognise conservation in the displacement before the interior volume situations, in this subsequent investigation, where the displacement volume situation was different from that in the prior investigation, some children were found to recognise conservation in the interior before the displacement volume situations. As there seemed to be no real reason why conservation of space taken up by an object should be easier or harder to recognise than conservation of room inside an object, the influence of the particular situation presented to the children was studied.

Without giving a detailed analysis of all the differences between the displacement volume situations in the two investigations (see the appendices of chapters 3 and 4), it can be noted that neither the initial explanation of displacement nor the more concrete less verbal presentation of the conservation problem is the whole reason for the different results. When in the pre-test of the present investigation, the initial explanation of displacement was omitted, the children still recognised conservation in the one, i.e. the original, displacement situation. That is, when the preliminary displacement demonstrations were identical but the ensuing displacement situations different the children responded differently. It was not the explanation alone that made the difference in recognition of conservation of displacement volume when conservation of interior volume was recognised, but it may well have influenced the conservation of displacement volume, in the prior investigation, when conservation of interior volume was not recognised. The connection shown between space taken up and water rise may well have facilitated conservation in the displacement volume situation when conservation was not recognised in the interior volume situation, though it does not determine conservation as against nonconservation in the different displacement volume situations when the conservation of interior volume is already recognised.

Likewise the concreteness of the situation is only part of the reason for the different results in the different displacement volume situations. The difficulty is not simply in the more abstract more verbal nature of the one displacement volume situation. When in the same relatively abstract verbal situation different questions are asked, conservation is recognised for interior volume and even for space taken up though the water level is thought to be different. However, the actual transformation and presence of a comparison object may facilitate the recognition that the water level would be the same after transformation of the object. The enaction of the transformation may bring out the possibility of reversing the transformation and the comparison object may be a reminder of what was before, that is, the one displacement volume situation may emphasise conservation rather than displacement especially as the object is not actually in water. Possibly the children are helped by the visual experience of the actual transformation of the same amount of material; information through the senses may emphasise that the same material is made different in appearance. In brief, conservation of interior volume and space taken up is recognised in the more abstract verbal situation as well as in the more concrete situation but the fact that the water level would be the same after the object was transformed is not recognised in the more abstract verbal situation, though it is in the more concrete situation. The abstractness of the displacement situation may be part of the reason for the difference in the children's responses; that is, it may hinder the recognition that the water level would be the same but it does not affect the recognition of conservation of interior volume or of space taken up.

So far it has been argued that the explanation of displacement may facilitate conservation of displacement volume when conservation of interior volume is <u>not</u> recognised, but it does not account for the fact that some children who have not had this explanation of displacement recognise conservation of displacement volume in one situation but not in another when conservation of interior volume <u>is</u> recognised. Further it has been argued that the concreteness of the situation may facilitate the recognition that the water level would be the same but it does not account for the fact that children are able to recognise conservation of space taken up without the concrete situation. Perhaps the difference in the children's responses was due to a different emphasis in the two displacement volume situations. The one situation, as has been suggested above, emphasises reversibility and conservation, whereas the other situation, with the object in the water and no actual transformation nor comparison object, emphasises displacement. Reversibility is not directly applicable, i.e. not enactable. The question becomes more one of displacement than of conservation, of water level rather than of taking up space, and this may evoke confused considerations of only partially understood effects. Conservation of displacement volume involves conservation of the object and of water as well as the understanding of the relation between them. The understanding of conservation of displacement volume involves an understanding of displacement as well as of conservation - two separate though here related ideas. These children apparently do not understand the causal relation between an object's taking up space in water and the displacement of the water though they know the water level will rise when an object is immersed in water; they give conservation judgments for space taken up but still think the water level will not be the same. No child mentioned the possibility of an object's floating if it were spread out and all the children realised the object would still be on the bottom of the dish.

Whether or not it is displacement rather than conservation that these children do not understand, and no matter what exactly in the different displacement situations creates the difference in difficulty, the importance of the particular situation in presenting problems of conservation of volume is clear. Specification of details of particular conservation situations therefore seems important as does the use of basically similar situations when studying any sequence in the development of conservation.

The teaching of conservation in the volume situations is next to be considered. Identity of material or amount and the possibility of reversing transformations do not necessitate volume conservation, for example in the case of space occupied by water turned into ice or into steam or in the case of room inside a squashed container; but in the volume situations involving blocks and plasticine in this experiment, identity and reversibility hold as reasons for volume conservation judgments. To nonconserving children, however, the fact that the same material can be made back as it was before may not seem incompatible with the judgment that the present volume differs from that of the original transformation; where identity or reversibility alone are pointed out they may seem irrelevant as reasons for conservation of volume because the present apparent difference in volume is not thereby negated. Children may accept the fact of identity or the possibility of reversibility yet not relate these to and recognise conservation in the volume situations; one child, for example, manipulated and recognised reversibility but frowned when it was pointed out as a reason for volume conservation and persisted "but there's not the same room in it now" and another child said "it's the same blocks but they take up more room".

In teaching volume conservation, the experimenter's explicit recognition of differences in appearance seemed particularly to encourage the children's understanding. The experimenter indicated her awareness of perceptual differences but pointed out compensation reasons for conservation judgments; compensation may not entail conceptual rather than perceptual judgment but to the children it was relevant to the present situation. The distinction between reality and appearances was made by recording displacement; marking off the water level provided the essential proof of the conservation of space taken up.

An explanation of conservation involves more than a single reason; it is strengthened by empirical evidence of conservation and by a clearly constructed argument from identity and reversibility to conservation. The combination of counting for identity, manipulating reversibility, measuring displacement, and verbalising these and compensation reasons builds a case for conservation. Several demonstrations and reasons per situation were important to the effectiveness of the teaching. When fewer reasons for conservation were given the teaching was less positive; there was less force in the argument and less authority in the explanation when there was no amassing of reasons. Likewise more than a single situation appeared to be important in the teaching of volume conservation; not all children recognised conservation in the displacement situation after recognising conservation in the interior volume situation even when they had been taught using the full teaching scheme.

Looking at the post-test results certain points seemed clear and certain questions remained to be answered. It was clear that the revised-full method of teaching volume conservation and group teaching are as effective as the original-full method and individual teaching. Likewise, it seemed clear that the development of conservation is not an all or none phenomenon and that there is a difference in degree of understanding with the different amount of experience given to different children. The question of essential elements in the development of a concept of conservation remained unanswered; the minimum conditions necessary for the development of broad understanding of conservation were not determined. In addition, the question arose as to whether a method could be devised to develop conservation of number, substance, weight, length, distance, area and volume all in one teaching session.

The prior investigation of the development of a concept of volume conservation had shown that an understanding of conservation in the Piaget-type interior and displacement volume situations can be developed in a wide range of E.S.N. children. Thirty such children had been individually taught using quite a full method which included three basic experiences and reasons for conservation, three volume situations, two of the basic experiences for conservation in each of the three situations, and the actual filling of containers in the interior volume situations. All of these children, total as well as partial nonconservers, learned to recognise, generalise, and give reasons for conservation. Thus it had been demonstrated that it is possible to develop a broad understanding of conservation in E.S.N. children.

In the present investigation of the development of a concept of volume conservation, each of five teaching schemes was designed to provide answers to several different questions. The results of the first teaching scheme showed that a simplified but still quite full method is effective in developing children's understanding of conservation whether they are individually or group taught. Six children, all total nonconservers, were given teaching which included the three basic experiences and reasons for conservation, the three volume situations but only one of the basic experiences, though all three of the reasons still, for conservation in each of the three situations and no containers for the consideration of interior volume. Two of the children were individually taught and four were taught as a group. All six children learned to recognise, generalise, and give reasons for conservation. More than a mere verbal response was learned. This was evidenced in the following ways: First, all the children gave negative as well as positive judgments, i.e. judgments of inequality as well as equality. Secondly, the children's reasons were not expressed in a single way, e.g. one boy expressed his identity-type reasons for volume conservation "they're the same many still", another "it's the same lot", a third "you haven't taken none away", and the children often made additional comments, e.g. "you've just split it up" or "you've only moved it a bit". And thirdly, no simple verbal cue was given, the conservation questions for the different attributes were not worded identically, yet all the children recognised conservation of all three attributes. Thus it was demonstrated that a genuine understanding of conservation can be developed using a simplified but still varied teaching scheme in a group as well as individual situation. The revised full method is effective in developing a broad and lasting understanding of conservation and it does not necessitate individual tuition nor an isolated room.

The results of the second teaching scheme provided no clear answer to the question of essential elements but did reveal the different degrees of understanding which may result from the omission of different experiences and reasons in teaching different children. When each one in turn of the three basic experiences and reasons for conservation was omitted from the teaching and an otherwise identical method was used as was used in the first teaching scheme, all three pairs of children, individually taught with a different experience and reason per pair omitted, improved in understanding conservation but not all the children developed a broad concept of conservation. The differences in degree of understanding, though not related in a simple way to the particular experiences and reasons omitted, did indicate that the development of a concept of conservation is not an all or none affair.

The results of the third teaching scheme, like the results of the second, showed that the development of a concept of conservation is not all or none. The four children, all total nonconservers, taught together using a teaching method from which the block displacement situation was omitted, the plasticine displacement situation different from that in the other teaching schemes, and the teaching again similar to that of the first teaching scheme except that the experimenter rather than the children manipulated the materials, developed different degrees of understanding of conservation. Again, essential elements were not isolated.

The results of the fourth teaching scheme revealed that the further reduction in experiences and reasons and situations further decreases the general effectiveness of the teaching of conservation. Particular essential elements, however, were still not clear. When, in turn, one only of the three basic experiences and reasons for conservation was included in the teaching, and only two volume situations presented, but an otherwise similar teaching method used as was used in the first teaching scheme, the children in the three pairs, individually taught with a different experience and reason per pair, did not respond to the same extent. Children who had previously been total nonconservers did not learn from any single experience and reason as presented in the two volume situations, whereas children who had previously been partial nonconservers did learn from any one experience and reason given in the two situations. The importance of the individual child's prior understanding became clear.

Finally, the results of the fifth teaching scheme indicated that verbalisation alone of a single reason for conservation is insufficient for the development of a concept of conservation. When identity-type or reversibility-type reasons were merely verbalised in the three volume situations, the two pairs of children, individually taught and all previously partial nonconservers, did not develop in understanding of conservation.

These five teaching schemes with their different effect on the children's understanding of conservation throw light on the development of a concept of conservation. The development of understanding of conservation was found not to be all or none but gradual; the post-test revealed differences in degree of understanding with different amounts of experience for different children. The differences in degree of understanding were related not only to the teaching given but also to the individual children's prior understanding. Although the reduction in number of experiences, reasons and situations presented in the teaching schemes resulted in a comparable decrease in understanding of conservation, the effect of the elimination of particular elements was not clear because different children given the same teaching responded differently. On the whole, however, the second teaching scheme was less effective than the first and perhaps slightly less effective than the third (where all the children had been total nonconservers), the fourth teaching scheme was again less effective than the first three schemes, and the fifth still less effective; but individual differences in the children's responses to the teaching schemes were great. Children who had previously been partial nonconservers learned with less teaching and in three cases volunteered reasons for conservation which had not been included in their teaching. Individual differences in personality, ability, age, etc. also influenced the recognition of conservation, the number and clarity of reasons given, the confidence and speed in answering etc., but the effect of children's prior understanding of conservation, as evidenced in the pre-test situations, was more clear cut; the children's responses to the reduced methods of teaching conservation, as evidenced in the post-test situations, could be clearly related to their prior understanding.

The influence of the children's prior understanding on the development of a concept of conservation has practical implications. It would seem important to assess the children's prior understanding of conservation of several attributes, as well as the one to be taught, and perhaps their understanding in related areas, such as one to one correspondence, in order to give the most appropriate and efficient teaching. As well as attempting to define the experiences, reasons, and situations necessary in the teaching of a concept of conservation, it is important to consider the individual children's conceptual development and adapt the teaching accordingly, e,g. a fuller teaching scheme may be necessary for total nonconservers than for partial nonconservers. It might ultimately be possible to order essential experiences, reasons etc. for different degrees of prior understanding, but the best, i.e. the most practical, teaching method might still be the one that is most effective in developing a broad concept of conservation in <u>all</u> children regardless of the degree of their prior understanding.

While the results of the five different teaching schemes revealed the effect of the interaction between children's prior understanding and the fullness of the teaching in the development of understanding of conservation as well as the fact that the development is not all or none, the minimum conditions for such a development were not defined. Although clear differences in degree of understanding of conservation resulted from reductions in the teaching (i.e. in the first teaching scheme all the children developed a broad understanding whereas in the second, third, fourth, and fifth schemes progressively fewer learned despite the fact that children with lower mental ages had been given the fuller teaching schemes), individual differences, especially in partial versus total nonconservation, complicated the effects of the elimination of different experiences, reasons, and situations. No clear relation was found between particular cuts in the teaching and different degrees of understanding, as evidenced for example in the number of situations where conservation was recognised. Further work might answer the question of or isolate essential elements in the development of understanding of conservation. Only a small number of children were given each teaching scheme and further teaching schemes could be devised to analyse the role of particular experiences, reasons, and situations. It remained to be shown whether and which particular experience and/or reasons are necessary. It may be that a minimum combination rather than a single element is essential, as seemed to be indicated by this investigation, and this minimum may be different for different children, as was also indicated by this investigation.

The whole question of essential elements may be unrealistic. This investigation showed that, in general, a reduced teaching method results in less understanding of conservation while a varied full one develops a thorough understanding. The practical importance of a varied full teaching method for giving <u>all</u> children a broad understanding of conservation was clear. If, however, a search for essential elements were to be carried out, some of the many aspects of the teaching of conservation which would need to be considered include: group versus individual tuition, particular experiences and reasons for conservation, number and type of situations presented, and individual differences. This by no means includes all the aspects which may influence the development of a concept of conservation and under each can be subsumed several considerations, e.g. under experiences - manipulation versus demonstration. These aspects would need to be studied separately and in relation to each other, e.g. individual differences in relation to group tuition and number of experiences, reasons, and situations. Without exploring all the possible interactions, several studies could be carried out to discriminate more clearly the most important elements, individual and group minimums, minimum variations, minimum combinations etc. For example, one situation only, the block displacement situation, could be presented with three experiences and reasons given, or verbalisation alone but of three reasons in three situations could be tried, or no verbalisation at all included while demonstrations and manipulations in three situations of reversibility, displacement and counting were made, or the same reduced method could be tried with groups and individuals to see if children learned less or more when in a group, or, finally, some partial and total nonconservers could be given teaching which included one experience, reason and situation while other partial and total nonconservers could be given teaching which included three experiences, reasons and situations.

To conclude, pre-testing, teaching, and post-testing results all revealed the gradual, not all-or-none, development of understanding of conservation. In the pre-testing, children were found who gave conservation judgments in some volume situations but not in others, i.e. in the original but not in the revised displacement situations. In the teaching sessions children often recognised conservation in one situation but not in the next. And in the post-testing children were found who recognised conservation in the displacement situations, both revised and original, but not in the interior volume situations. The recognition of conservation in some but not other situations was not just a practice effect; children recognised conservation in prior but not in later situations, e.g. in displacement volume situations but not in substance or weight situations. Further, the extent of the children's understanding of conservation was shown to be related to the fullness of the teaching they had been given as well as to their prior understanding of conservation. It would therefore seem best in teaching conservation to include a variety of experiences, reasons, and situations to develop a broad understanding of conservation as well as to allow for individual differences in prior understanding and in what and the way children learn.

Pre-testing Procedure for Investigation Three.

1a. Here are two balls of plasticine (two identical balls approximately $1\frac{1}{2}$" in diameter)

Is there the same amount of plasticine in each ball?
If you have this ball and I have that one (pointing) have we equal amounts of plasticine, fair shares?
(After recognition of equality or making equal)
If I do this to mine (roll one ball into sausage approximately $3\frac{1}{2}$" long)
Is there still the same amount of plasticine?
Do we have equal amounts of plasticine, fair shares?
Do our shares still look the same?
(Remake two balls and repeat questions cutting plasticine ball into two and then four pieces)

1b. Here are two glasses of orange drink (two identical 100ml beakers $\frac{1}{4}$ full)

Is there the same amount of orange drink in each glass?
If you have this one and I have that one (pointing) have we equal amounts to drink, fair shares?
(After recognition of equality or making equal)
If I do this to mine (pour one drink into low wide dish)
Is there still the same amount of orange drink?
Do we have equal amounts to drink, fair shares?
Do our shares still look the same?
(Repour drinks into original glasses and repeat questions dividing drink into two 50ml and then four 25ml beakers)
Here are two glasses of orange drink (one 100ml beaker $\frac{1}{4}$ full, other 100ml beaker $\frac{3}{4}$ full)
Have we the same amount of orange drink, equal amounts to drink, fair shares?

2a. Here are two balls of plasticine (two identical balls approximately 1" in diameter)

Do they weigh the same?
Are they equal in weight?
(After recognition of equality or making equal)
If I do this to this one (flatten one ball into pancake approximately $2\frac{1}{2}$" in diameter)

Does it still weigh the same?
Are they equal in weight?
Do our shares still <u>look</u> the same?
(Remake two balls and repeat questions cutting plasticine ball into two and then four pieces)

2b. Here are two balls of plasticine (two equal in weight, approximately 200 g, but different in size one approximately $1\frac{3}{4}$" in diameter, other approximately 1" in diameter)
There is something inside each ball
Do they weigh the same?
Are they equal in weight?
(After recognition of equality or making equal)
If I do this to this one (roll one ball approximately $4\frac{1}{2}$" long and twist it)
Does it still weigh the same?
Are they equal in weight?
Do our shares still <u>look</u> the same?
(Remake two balls and repeat questions cutting plasticine ball into two and then four pieces)
Here are two balls of plasticine (one two times as large and heavy as the other)
Do they weigh the same, are they equal in weight?

3a. Here are two buildings (two 6x3x2 1 cm wooden-unit-cube buildings)
Have they the same room in them as each other?
If you lived in this one and I lived in that one would we have equally much space inside our buildings "to live in"?
(After recognition of equality)
If I do this to mine (make 12x3x1 building out of 6x3x2 building)
Does my building still have the same room in it?
Do our buildings have equally much space inside them?
Do our buildings still <u>look</u> the same?
(Remake two buildings 6x3x2 and repeat questions separating one building into two and then four overlapping parts)

3b. Here are some blocks (4x3x3 1cm metal unit cubes) and a dish of water (perspex container 5"x3"x2")
I'll mark where the water comes to
Watch what happens to the water level (pointing) when I put the blocks in the water (demonstrating)
If these blocks were spread along the bottom of the dish Would the water level be the same as now, come to the same place?
Would these blocks still take up the same amount of room in the water, leave equally much room for water?
(Repeat for if the blocks were part at this end and part at that end of the dish and for if the blocks were part in each of these corners)

3c. Here is a ball of plasticine (approximately 1" in diameter) and a dish of water
I'll mark where the water comes to
Watch what happens to the water level (pointing) when I put the plasticine in the water (demonstrating)
If this plasticine were in a ring on the bottom of the dish Would the water level be the same as now, come to the same place?
Would this plasticine still take up the same amount of room in the water,
Leave equally much room for water?
(Repeat for if the plasticine were part at this end and part at that end of the dish and for if the plasticine were part in each of these corners)

If the child gave conservation answers in 3a. and nonconservation answers in 3b. and 3c. the following situations were presented:

3b*. Here are some blocks (4x3x3 1cm metal unit cubes) and a dish of water (perspex container 5"x3"x2")
I'll mark where the water comes to
Watch what happens to the water level (pointing) when I put the blocks in the water (demonstrating)
Here are two lots of blocks (two lots 4x3x3 1cm metal unit cubes)
Would they make the water level rise the same, rise equally far?

Would they take up the same amount of room in the water, leave equally much room for water?
(After recognition of equality)
If I do this (make one lot of blocks 6x6x1)
Would they still make the water level rise the same, rise equally far?
Would they take up the same amount of room in the water, leave equally much room for water?
Do they still look the same?
(Remake two lots 4x3x3 and repeat questions separating one lot into two and then four overlapping pieces)

3c*. Here is a ball of plasticine (approximately 1" in diamter) and a dish of water (perspex container 5"x3"x2")
I'll mark where the water comes to
Watch what happens to the water level (pointing) when I put the plasticine in the water (demonstrating)
Here are two balls of plasticine (two approximately 1" in diameter)
Would they make the water level rise the same, rise equally far?
Would they take up the same amount of room in the water, leave equally much room for water?
(After recognition of equality)
If I do this (make one plasticine ball into a ring)
Would they still make the water level rise the same, rise equally far?
Would they take up the same amount of room in the water, leave equally much room for water?
Do they still look the same?
(Remake two balls and repeat questions cutting plasticine ball into two and then four pieces)
Here are two balls of plasticine (one four times as large as the other)
Would they make the water level rise the same, rise equally far, take up the same amount of room, leave equally much room for water?

Post-testing Procedure for Investigation Three.

1. Repeat pre-test 3a
2. Here are two blocks of flats (two buildings made of 36 Lego cubes 1x3x12 high)
   Have they the same room in them as each other?
   If you lived in this one and I lived in that one would we have equally much space inside our buildings "to live in"?
   (After recognition of equality)
   If I do this to mine (make one into 1x2x18 high building)
   Does my building still have the same room in it?
   Do our buildings have equally much space inside them?
   Do our buildings still look the same?
   (Remake two buildings 1x3x12 high and repeat questions making one into 1x1x36 high and then 12x3x1 high)
3. Repeat pre-test 3b but reword first question:
   Where would the water level be, where would the water come to?
4. Repeat pre-test 3c but reword first question:
   Where would the water level be, where would the water come to?
5. Repeat pre-test 3b*
6. Here are two lots of blocks (1 lot 9x2x2 1cm metal unit cubes and other lot 9x2x1 1cm metal unit cubes)
   And here are two bowls of water (two perspex containers 5"x3"x2" with water coming up just as far in each)
   Would they make the water level rise the same, rise equally far?
   Would they take up the same amount of room in the water, leave equally much room for water?
   (After recognition of inequality)
   If I do this (make 9x2x2 into 9x4x1)
   Would they make the water level rise the same as each other, rise equally far as each other?
   Would the two lots take up the same amount of room as each other in the water, leave equally much room as each other for water?

(Remake one 9x2x2 and repeat questions making other 9x1x2 high and then first one 12x3x1 high)

7. Repeat Pre-test 3c*

8. Here are two pieces of plasticine (2 discs of plasticine one two times as large approximately $\frac{3}{4}$" thick and $2\frac{1}{2}$" across as the other approximately $\frac{3}{4}$" thick and $1\frac{1}{2}$" across but of equal weight 10 grammes)

   And here are two bowls of water (two perspex containers 5"x3"x2" with water coming up just as far in each)

   Would they make the water level rise the same, rise equally far?

   Would they take up the same amount of room in the water, leave equally much room for water?

   (After recognition of inequality)

   If I do this (make larger disc into ball)

   Would they make the water level rise the same as each other, rise equally far as each other?

   Would the two pieces take up the same amount of room as each other inthe water, leave equally much room as each other for water?

   (Remake disc and repeat questions making one into cube and other into cylinder)

9. Repeat pre-test 1a and 1b.

10. Repeat pre-test 2a and 2b

CHAPTER 5

THE DEVELOPMENT OF UNDERSTANDING OF CONSERVATION IN A GENERAL SENSE AND AREA CONSERVATION

I INTRODUCTION

Investigations One, Two and Three showed that understanding of conservation of weight and volume can be developed in educationally subnormal children. The aim of Investigation Four was to find out whether conservation of quantity in a general sense and conservation of area can be successfully taught to such children. The investigation was designed to study conservation in a wider range of attribute situations than previously studied. The sequence, recognition of conservation of substance-before-weight-before-volume, had been found to hold for ESN children; the possibility of a further sequence including number, length, distance and area situations was explored in this investigation. The influence of situational differences on recognition of conservation was likewise further studied. And finally, the more extensive pre-test enabled further investigation of the role of initial understanding.

The prior investigations indicated that a diversified teaching method is most generally effective, that the degree of understanding developed is related to the extent of the teaching given, that the development of conservation concepts is not all or none, and that different children learn with different explanations and experiences. Part of the purpose of the present investigation was to try out a brief general method for teaching educationally subnormal children to recognise conservation in diverse situations. If it were to be found possible to develop understanding of conservation of quantity in a general sense, it would not be necessary to design further separate methods to teach conservation of different attributes. In order to find out if understanding developed in this general way was as sound as that developed by teaching conservation of a single attribute, conservation of area was taught to a matched group of children and both groups of children were given the same post-test.

Understanding of conservation may be distinguished from understanding of the attribute conserved; recognition of conservation in different situations may be developed separate from a detailed understanding of particular attributes, though conservation can only be demonstrated in conjunction with physical attributes. To develop an understanding of conservation in a general sense, therefore, it may be unnecessary to consider in any detail the specific attributes conserved.

The possibility of teaching conservation of quantity as a general principle in a range of attribute situations was studied in this investigation, but there was no question of teaching a completely general concept of conservation for several reasons including the following. 1. Conservation is not unexceptionable as a physical phenomenon (e.g. volume changes as water is turned from ice to steam). 2. There are situations in which conservation of one attribute holds while conservation of another does not (e.g. conservation of area but not perimeter and vice versa). 3. Understanding of conservation has not been found to develop in an all or none manner (e.g. the recognition of conservation of an object is evident years before conservation of volume).

In The Child's Conceptionof Geometry, Chapt. 11, Piaget makes a distinction between interior, or enclosed, and complementary area. Interior area is the area "within a closed figure" and complementary area is that "outside the closed figure". Piaget found that conservation of interior area appeared before that of complementary area. In situations in which the shape of a potato plot was altered by separating it into sections which were not all alike or by transforming the original square to an elongated rectangle, or in situations in which the form of the remaining areas, fields instead of plots, was altered, Piaget found children who granted the equality of the interior areas though not that of the complementary areas. Some of these children recognised the equality of interior area only where the transformation was slight and gave no reasons for conservation; when the transformation was greater they did not recognise the equality of either the interior or the complementary area. Such children Piaget considered as at a transitional level and he classified them as non-conservers still. Other children recognised the equality of interior area, but not complementary area, whatever the modification in form, i.e. however remote from the original shape, and gave reasons of reversibility or identity or compensation. Such children Piaget classified as conservers of interior but not complementary area. He suggested that conservation of complementary areas is harder to construct than that of enclosed areas because

> "the child must not only understand the compensation between 'sites' which are occupied and those which are vacated but also the reciprocal relation between the area within an inner perimeter and the area outside. He must recognise that the latter is complementary with reference to a second outer perimeter. This reciprocal relation implies not a limited but an overall coordination of plane surfaces." (Piaget, Inhelder & Szeminska (1960) p.291)

An understanding of the "reciprocal relation" and "an overall coordination of plane surfaces", however, may not be necessary. Children may recognise conservation of complementary as well as interior area without such understanding and simply by recognising conservation of field and plot areas separately. To recognise conservation of both areas children need not deduce invariance of complementary area from that of interior area. In teaching area conservation in the present investigation, no explanation of such reciprocal relations was included. Further, the investigation sought to clarify whether conservation developed for 2 different types of area (i.e. whether potato plot area was considered differently from field area); or whether differences in difficulty in recognition of continuing equality could be explained more simply in terms of situational differences (i.e. whether any sequential order was simply a result of differences in the complexity of the transformations or situations). Because field as well as plot areas have perimeters and are therefore also enclosed, it would seem that any order would be one of situations differing in difficulty rather than different types of area. In brief, it may be unnecessary to make a distinction between understanding of conservation of interior area and understanding of conservation of complementary area. It was hoped that the present investigation would throw light on the question of recognition of equality in interior before complementary area situations as Investigations Two and Three had thrown light on a similar question in relation to conservation of interior and displacement volume.

Strictly conservation situations of Piaget's, Piaget (1952), Piaget & Inhelder (1941), Piaget, Inhelder & Szeminska (1960), were used in the present investigation of conservation of the 7 different attributes. This meant that every problem involved a transformation of material. For example, in the case of length, conservation situations were distinguished from length comparison situations (Piaget, Inhelder & Szeminska (1960) pp.91-92), likewise in the case of distance, conservation situations were distinguished from distance symmetry situations (Ibid.pp. 71-72), similarly in the case of area, conservation as opposed to addition/subtraction situations (Ibid.pp.261-262) were considered, and again in the case of volume, conservation as distinct from reproduction of equal volume (Ibid. pp.355-356) was required.

The criteria for classifying the children pre-tested as conservers or nonconservers of an attribute were the following: explanation of reasons for conservation and unexceptionable recognition of conservation of the attribute in question. If a child supported judgments of continuing equality with reasons of identity (i.e. that nothing had been added or taken away or that it was the same material etc.) or reversibility (i.e. that it was the same before or could be put back the same) or compensation (i.e. that one was more in one way but the other was similarly more in another way) and recognised conservation for all the transformations in all the situations presented for the attribute in question, then he was classified as a conserver. If, on the contrary, a child failed to recognise continuing equality, or recognised the equality for some transformations but gave no reasons for conservation and then did not recognise conservation for all the other transformations, or recognised and gave reasons for conservation in some but not all situations for an attribute, he was classified as a nonconserver. Although understanding of conservation does not develop in an all-or-none manner, for practical purposes a distinction can be made and criteria for conservation/nonconservation judgments defined. Within the category of nonconservers further distinctions were made between children who evidenced no recognition of continuing equality, children who made purely perceptual judgments of equality, and children who recognised and gave reasons for conservation in some but not other material situations for an attribute. In other words a distinction was made between perceptual and conceptual judgments of equality and between these and total non-recognition of continuing equality. Although there is a continuum extending from total non-recognition through purely perceptual recognition, through conceptual recognition in some but not other situations to clear conceptual recognition of continuing equality with reasons for conservation and in all the situations for an attribute, for this investigation distinctions at points along the continuum were made.

Similarly, the criteria for regarding the children given instruction as having developed genuine understanding of conservation were the following: generalisation of conservation to different and more complex situations as well as recognition of conservation in all the familiar attribute situations, clear explanation of reasons justifying conservation judgments in every attribute situation of the post-test, and also durability of the understanding of conservation developed, as evidenced on a second post-test two months after the teaching.

As far as the writer knows, no previous attempts have been made to develop understanding of conservation in the general sense attempted in the first teaching scheme of the present experiment, although generalisation of conservation of particular attributes taught has previously been studied. Conservation of area, considered in the second teaching scheme of the present experiment, has been taught in studies by Beilin & Franklin (1962) and Beilin (1966) but understanding in area "quasi-conservation" situa ions only was investigated. Beilin's "quasi-conservation" area tasks differed from Piaget's conservation tasks "principally in that the congruent figures were not rearranged before the eyes of the child. The child had to arrive at the judgment of equality with the patterns already altered". (Beilin (1964)).

II PROCEDURE AND RESULTS

One hundred and fifteen educationally subnormal schoolchildren aged between 8 and 16 with IQs between 47 and 81 were pre-tested for conservation in Piaget-type number, substance, length, distance, area, weight and volume situations. Fifty-one children who failed to recognise conservation for two or more attributes were grouped by 3s matched for chronological age, IQ and degree of conservation. Differences in age were usually less than 15 months and in IQ never more than 16 points. Each group of 3 contained children of exactly the same degree of understanding of conservation as evidenced on the pre-test. Seventeen children (9 nonconservers of area and volume, 3 nonconservers of area, volume and weight, 1 nonconserver of area, volume, weight and length, 2 nonconservers of area, volume, weight, length and substance, and 2 nonconservers of area, volume, weight, length, substance and number) were given instruction on conservation using one teaching scheme. A matched seventeen children were given instruction using a second teaching scheme. A control group of seventeen children, matched to the two teaching groups, were seen by the experimenter but were not given instruction on conservation. The thirty-four children given instruction ranged in age from 10 to 16 and in IQ from 50 to 77. The two experimental groups were post-tested one week and then two months after being given instruction. When the experimental groups were given their second post-test, the control group were given the pre-test for a second time.

The materials used were: 24 beads 2cm diameter, 2 transparent beakers 100ml, 1 low transparent dish 8cm wide, 1 tall transparent tube 2.5cm wide, 10 identical plastic flowers, 10 identical glass jars, 2 transparent beakers 100ml, 4 transparent beakers 25ml, 1 petri dish 9cm wide, orange drink, 2 balls plasticine 4.5cm diameter, knife, 2 sticks .5cm square and 20cm long, 2 sticks.5cm square and 10cm long, 4 Mueller Lyer arrowheads in black cardboard .05cm thick - arms 1cm wide 13cm long, reel of white paper tape 1cm wide, scissors, ruler, 2 model trees 6.5cm high, cardboard screen 10cm square with window 5cm square, wooden screen 10cm square and 2cm thick, 2 pieces of green perspex 30x20cm area, similar piece pre-cut into 3 parts 20x10cm each, 40 model houses 2x1x2cm high, piece of thin brown cardboard 12cm square, similar piece divided into 2 parts 12x6cm, similar piece divided into 4 parts 12x3cm, 2 pieces of thin brown cardboard 9cm square, 2 balls plasticine 4.5cm diameter, cotton wool, 72 wooden cubes 1cm side, 72 metal cubes 1cm side, clear perspex container 14x8x6cm, water, marking pencil, 1 ungraduated stick .5cm square 30 cm long, 2 pieces clear perspex - one 50x30cm marked in grid of 5x5cm squares and other 28x18cm in a grid of 4x3cm rectangles, 24 wooden cubes of 1.8cm side, sand, small funnel, 1 transparent flask 50ml, 2 balls plasticine-one 6cm diameter and other 5cm diameter, 2 wires 18cm long, 2 red felt coated cardboard rectangles 38x31 cm one pre-cut into two triangles, 2 blue felt circles 8cm diameter, 2 meccano lattices, 2 balls plasticine-one 7cm diameter and other 3.5cm diameter, 2 balls plasticine equal in volume but differentially weighted to 70g and 210g.

Throughout the investigation the experimenter again tried to avoid giving any extraneous or inadvertent cues by gesture, expression, or tone of voice. The situations and questions were presented so as not to bias the children's responses. The procedure was standard yet flexible. Care was taken that children understood the questions as they were intended.

(i) Pre-testing.

The pre-test included problems on conservation of number, substance, length, distance, area, weight, and volume. It was designed to answer several questions as well as to find children with different degrees of understanding to whom conservation might be taught. The questions to be investigated included the following. Is there a sequence in the development of recognition of conservation of the seven different attributes? Are there situational differences influencing the recognition of conservation of particular attributes? What is the influence of the degree of initial understanding of conservation on responses to the teaching? What is the extent of generalisation of taught conservation?

In order to study any sequence in the development of conservation concepts, conservation problems for seven different attributes were presented. These problems were not presented in a random or varied order, rather, attribute situations generally found to be harder were presented later to counteract any possible practice effect. In order to reveal any influence of particular situations or presentations, two different materials were used in investigating conservation of each attribute and more than one transformation of each material was made. Questions were worded similarly for the two material situations of each attribute. In other words, the language used for all questions concerning the same attribute was kept similar while the material conditions were changed. (Questions for conservation of different attributes, in contrast, were worded quite differently, for example, the word 'space' was used in relation to area only and the word 'room' in relation to volume only. This was done, in addition to putting very different attribute situations in juxtaposition, to ensure that children distinguished the particular attribute in question). The pre-test was also designed to enable the investigation of the influence of initial understanding on response to conservation teaching. A record of each child's responses to varied conservation problems was made before any teaching was carried out. The pre-test was likewise intended to provide for the study of generalisation of taught conservation, that is, to enable the comparison of pre and post-teaching recognition of conservation in several different situations.

A standard pre-test procedure was followed but if, in the course of administering the pre-test, further clarification of a child's understanding was necessary additional unbiased questions were included, e.g. "what about now" for a further transformation. Some flexibility in questioning was necessary so as to be sure child and experimenter fully understood one another. More than one wording was given for each question in every situation just as more than one transformation was made. Ambiguous words such as 'size' were avoided. Particular care was taken that the children understood that the question of sameness referred to specific attributes and not a general sameness, i.e. not a sameness to all appearances. Sameness in the sense of equivalence rather than identicalness was considered. Likewise, it was made clear that all the previous material was included for comparison.

No preliminary operational clarifications were included for the different attribute situations as it was possible to ensure that every child tested understood correctly terms such as 'same' and 'equal' in relation to the attribute being considered without making unnecessary preliminary demands on the child's attention. Inequality situations were included for every attribute and these clarified the understanding of terms as well as the fact that there was no agreement to sameness regardless of the actual situation. Negative options were not specifically expressed in conservation questions as these would have increased the verbal complexity and would not necessarily have unbiased the situation. The inequality situations, in any case, counterbalanced any biasing toward correct 'sameness' answers because in these situations any mere agreement to sameness without understanding would result in incorrect responses. Finally, the particular transformations made were clearly different from the originals in order to lessen the possibility of merely perceptual correct judgments.

In general, the conservation situations and questions were like Piaget's (see Piaget (1952) Chapts. 1 to 4, Piaget, Inhelder & Szeminska (1960) Chapts. 3 to 5, 11, & 14 and Piaget & Inhelder (1941) Chapts. 1 & 2). The materials used, the number of objects included, the transformations made, the wording of the questions etc. were generally similar to Piaget's. But, certain changes were made, i.e. different transformations included, and only strictly conservation situations were used, i.e. only situations where existing arrangements are modified and not equivalence situations where no actual transformations are included. Except in the cases of distance and Piaget's displacement volume, a comparison object or objects was present for all transformations in the conservation situations. Different materials were introduced and different transformations made, as well as differently worded questions asked, in the various attribute situations in order to emphasise the distinction between the attributes considered.

In testing for number conservation, Piaget's problems were presented (see Piaget (1952) Chapts. 2 & 3). Piaget reported using six to eighteen beads and transferring them into different containers. In this experiment six and then twelve beads were used. One container was carefully chosen so that the six beads, after being transferred, would be held clearly discrete in single file, and a different container was chosen for the larger number of beads so that they, when transferred, would not be clearly discrete. In Piaget's "provoked correspondence" situation, flowers were bunched and spread near and far from their jars. The number conservation questions were worded "same number" not "same amount" in order to distinguish the attribute to be considered, i.e. number rather than substance, in the discontinuous as opposed to continuous material situations.

Again in testing for substance conservation, Piaget's problems were presented (see Piaget (1952) Chapt. 1 and Piaget & Inhelder (1941) Chapt. 1). Containers different from those used in the number situation were used for liquid substance transformations which were presented before plasticine substance transformations. Conservation in the solid substance situation, sometimes found to develop later than conservation in the liquid substance situation, was tested after conservation in the liquid substance situation in order to counter any possible practice effect.

In testing for length conservation, Piaget's problems were used (see Piaget, Inhelder & Szeminska (1960) Chapts. 4 & 5) but certain changes were made. Sticks were placed between Mueller Lyer arrowheads, such as Smedslund (1964) used, in order to reduce the possibility of merely perceptual judgments of sameness in length which may be made when sticks are staggered the top or bottom stick to the right of the other. The length conservation situation involving strips of paper cut and positioned in different ways, was presented as Piaget described. In this situation, as in the staggered sticks situation, the starting and stopping points of the pieces were put out of alignment, whereas in the Mueller Lyer situation the pieces were still aligned. In asking the length conservation questions, care was taken that the children understood 'long' as used in the abstract-relative sense here rather than in an absolute sense. Likewise, the experimenter moved her finger along the lengths to be considered in order to clarify the question, i.e. to ensure that the children understood the lengths in question. The word 'distance' was not used in the length conservation situations.

In testing for distance conservation, Piaget's problem was presented (see Piaget, Inhelder & Szeminska (1960) Chapt. 3). Piaget's 50cm spacing of objects was followed and the reportedly easier divider situation was presented first, again to counter any possible practice effect. Care was taken that the children understood the distance to be considered, i.e. that they understood the question referred to going from object to object <u>not</u> object to divider and that it referred to going through not around or over the divider. The experimenter indicated a straight path between object and object signifying the objects by name. Questions of "symmetry" in the distance situation were not included; the children were not asked questions of distance going in both directions. Likewise, although questions of distance were raised in Piaget's study of movement and velocity concepts (Piaget (1946b)) and described by Flavell (1963, pp. 322-3), the situations considered there were not included in the present pre-test because they were not conservation situations.

In testing for area conservation, strictly conservation problems of Piaget's were presented (see Piaget, Inhelder & Szeminska (1960) Chapt11). Piaget's problem situation in which an existing arrangement of houses on a field is modified was used here first. A small number of houses on each of two fields was presented and one arrangement transformed, and then the same was done with larger numbers of houses; as before, the presentation was in an order to counter any practice effect. Piaget's rearranged shapes were incorporated into the second area problem situation of potato plots on fields. Questions of complementary as well as enclosed area were included in order to test for the sequential order Piaget found, i.e. in order to see if some children recognise conservation of enclosed before complementary area. Though Piaget (in the chapter cited above) does not give the actual dimensions of his potato plots nor details of the transformations made, a situation similar to his was used in the present pre-test in order to reveal any sequence or situational differences. No actual model cows were introduced into the fields but they were mentioned if it were necessary to clarify the questions. No questions were asked in terms of grass to eat because the quantity of grass in each of two fields may be different even though the areas of the two fields are the same. Apart from avoiding this particular expression of the questions, the area conservation questions were worded as Piaget's were.

In testing for weight conservation, Piaget's problems were used with little change (see Piaget & Inhelder (1941) Chapt. 2). Both plasticine and cotton wool shapes were transformed and questions asked as Piaget had.

Finally in testing for volume conservation, Piaget's problems were again used (see Piaget, Inhelder & Szeminska (1960) Chapt. 14) but an additional displacement volume situation unlike Piaget's was included to clarify children's understanding. Piaget's interior and displacement volume situations were presented and were followed-up by a displacement situation in which there was an actual transformation of material and a comparison object. Only unit cubes, and not plasticine, were included in the displacement situations as no difference had been found using the different materials in the prior investigations. The wording of the volume conservation questions was like Piaget's.

(Detailed description of the pre-testing procedure is given in the chapter appendix.)

Each child was seen alone for approximately 30 minutes and sat at a right angle to the experimenter at a table in a quiet room of the school. Throughout the pre-test the experimenter made all the transformations in full view of the child. After a child made a judgment, the experimenter made only noncommittal remarks and in an unchallenging manner asked the child why he thought what he did. A child's explanations of his judgments were taken as evidence of conservation or nonconservation. Each child's performance on the pre-test was recorded on a standard form and, as far as possible, the child's exact comments were taken down.

The criterion for nonconservation of an attribute was failure to recognise equality in the attribute after material was transformed in shape while also giving a clear indication of which portion was considered greater or less and why. If a child maintained equality in an attribute for the first transformation presented but gave no reason for conservation and then gave nonconservation judgments for the later transformations, he was regarded a nonconserver. Care was taken to distinguish purely perceptual judgments of equality from conceptual judgments of conservation.

Reasons for conservation judgments taken as evidence of genuine concepts of conservation included: the recognition that 'it was the same before', that 'it could be put back the same', that 'the other could be put the same' (i.e. reversibility-type reasons), and the recognition that 'it was the same absolute number - 6, 12, or 10, material, amount, length, size, weight,' etc., that 'none had been added or taken away' (i.e. identity-type reasons), and the recognition that 'it was more in one direction but less in another' (i.e. compensation-type reasons).

Of the one hundred and fifteen educationally subnormal children pre-tested, fifteen were nonconservers of 6 attributes (number, substance, length, weight, area and volume), eighteen nonconservers of 5 attributes (substance, length, weight, area and volume), three nonconservers of the 4 attributes (substance, weight, area and volume) and five nonconservers of the 4 attributes (length, weight, area and volume), one was a nonconserver of the 3 attributes (length, area and volume) and sixteen nonconservers of the 3 attributes (weight, area and volume), thirty-seven were nonconservers of 2 attributes (area & volume), two non-conservers of volume only and eleven nonconservers of area only, and seven were conservers of all 6 attributes (number, substance, length, weight, area and volume). All one hundred and fifteen recognised the continuing equality in the distance situation.

The following table gives the number and the CA, IQ and MA ranges of the children with the different degrees of non-conservation.

	N	CA Range		IQ Range		MA Range	
Nonconservers:							
Vol Area Wt Len Subs No	15	8. 6	16. 2	50	79	5. 1	10. 6
Vol Area Wt Len Subs	18	8. 4	16. 0	53	79	4. 5	11. 8
Vol Area Wt - Subs	3	9. 3	14. 1	47	77	4. 4	8. 9
Vol Area Wt Len	5	11. 9	15. 0	55	72	8. 0	9. 0
Vol Area - Len	1	15. 1	15. 1	61	61	9. 2	9. 2
Vol Area Wt	16	9. 4	15. 10	55	81	6. 6	11. 9
Vol Area	37	9. 5	16. 1	57	77	5. 4	12. 0
Vol	2	11. 3	13. 7	70	75	7. 5	9. 7
- Area	11	12. 8	15. 5	57	77	7. 8	11. 5
Conservers:							
Vol Area Wt Len Subs No	7	10. 5	16. 0	59	87	6. 8	10. 6

As shown in the table, the lowest mental age found among children who recognised conservation of all 6 attributes was 6. 8 (CA 10.5) and the highest mental age found among children who failed to recognise conservation of all 6 attributes was 10. 6 (CA 13.4).

The foregoing description of the findings in pre-testing the children indicates the general pattern of the children's recognition of conservation, but does not distinguish differences in the children's responses to different situations for the same attribute. Recording the children as nonconservers of an attribute unless they recognised conservation in both pre-test situations for the attribute, clarified the basic underlying sequence in the development of recognition of conservation, but did not show the influence of differences in the particular situation upon such recognition. The following table records these situational differences within the overall pattern of the children's responses.

Nonconservers:		N
Vol Area Wt Len Subs No	Ncrs all six in full	9
	all but Flower No	4
	all but Beads No & Liquid Subs	1
	all but Flower No & Plast.Subs	1
Vol Area Wt Len Subs	Ncrs all five in full	13
	all but Liquid Subs	5
Vol Area Wt - Subs	Ncrs all four in full	1
	all but Liquid Subs	2
Vol Area Wt Len	Ncrs all four in full	5
Vol Area - Len	Ncrs all three in full	1
Vol Area Wt	Ncrs all three in full	15
	all but Interior Vol	1
Vol Area	Ncrs both in full	30
	Area & Piaget Displ Vol only	5
	Area & Interior Vol only	1
	Area & both Displ Vol only	1
Vol	Ncrs Interior Vol only	1
	Piaget Displ Vol only	1
Area	Ncrs 12 & 20 Houses only	9
	12 & 20 Houses & Plots	2

Looking at the pre-test findings it was clear that, although there were some individual variations and some differences in responses to different situations, there was a sequence in the development of recognition of conservation in these ESN children. The pre-test results support Piaget's emphasis on the sequential development of conservation over and above age differences. Despite the ranges in CA, IQ and MA for the same levels of nonconservation, the pattern of recognition of conservation was basically the same. To put it another way, although there was no simple relation between degree of conservation and age (chronological or mental) or IQ, there was a definite order in which conservation of the different attributes was recognised. This is in accord with Piaget's findings that the sequence of development of conservation concepts is unvarying but the ages at which the concepts develop may vary.

The sequence recognition of conservation of substance-before-weight-before-volume was again found. Twenty children recognised conservation in all substance but in no weight and volume situations. No children recognised conservation in the weight or volume situations who failed to recognise conservation in substance situations. Thirty-one children recognised conservation in all substance and all weight but in no volume situations. No children recognised conservation in the volume situations but failed to recognise conservation in both substance and weight situations. One child, only, conserved in a volume situation as well as in substance situations but not in any weight situations.

In addition to verifying the basic sequence conservation of substance-before-weight-before-volume, the pre-test revealed an overall sequence recognition of conservation of distance-before-number-before-substance & length-before-weight-before-volume & area. Although there were situational differences within the more general sequence and further investigation is necessary, an overall pattern in the development of recognition of conservation of the seven attributes pre-tested was apparent.

Recognition of continuing equality in the distance situation appeared first. All one hundred and fifteen children appeared to recognise conservation of distance, but, as will be argued later, a perceptual judgment may be all that is made in the distance situation. Conservation of number appeared second.

Thirteen children recognised conservation in the number situations but not in any substance, length, weight, area and volume situations. No children recognised conservation in any of these latter five attribute situations who failed to recognise number conservation. The place of length conservation in the sequence is less easily defined. One child, only, recognised conservation in the length situations but not in the substance situations; six children did the reverse and recognised substance before length conservation. Sixteen children recognised length conservation but not weight conservation; only one child did the reverse and recognised weight before length conservation. Fifty-eight children recognised length conservation but not area conservation and forty-eight length but not volume conservation. No children recognised area or volume conservation who failed to recognise length conservation. Thus, length conservation can be said to precede weight, area, and volume conservation but not substance conservation. Conservation of substance was recognised before conservation of weight and volume, as already reported; it was also recognised before conservation of area. Sixty-one children recognised substance but not area conservation. No children recognised conservation of area but not substance. Weight conservation appeared fifth in the sequence. It was recognised before volume conservation, as previously reported; and it was likewise recognised before area conservation. Forty children recognised conservation in weight but not area situations. No children recognised conservation of area but not weight. Last in the sequence appeared area and volume conservation. Two children recognised conservation in volume but not in any area situations. No children recognised conservation in area but not in any volume situations. Eleven children failed to recognise area conservation only; two children failed to recognise volume conservation only. Thus, recognition of area conservation appeared to be the most difficult for the children.

The criterion used in arriving at the aforementioned attribute sequence was <u>total</u> conservation and nonconservation for the attributes said to arise in sequence. In other words, when conservation of one attribute was said to arise before conservation of another, the children had recognised conservation in all situations for the particular attribute said to arise first and failed to recognise conservation in all situations for the particular attribute said to arise later.

This overall sequence in the development of recognition of conservation was quite clear, but situational differences, as also recorded, complicated the picture. Differences in the material situation presented for an attribute influenced the children's recognition of conservation in the case of volume, substance, number and area; and, in addition, differences in the particular transformations made influenced the recognition of continuing equality in the case of length and area. Where children were said to 'recognise conservation' they had given reasons for their judgments; where they were said to 'recognise continuing equality' they had not given any reasons. Thus, a conceptual recognition of conservation was distinguished from a perceptual recognition of equality. In the volume, substance, number and area situations, more than perceptual judgments were made when children recognised and gave reasons for conservation for all transformations in any one situation though not in all the situations for the attribute being considered. In the length and area situations, purely perceptual judgments of equality were given when children recognised equality for some but not other transformations in any one situation and gave no reason for conservation.

In the following cases differences in the material situation gave rise to differences in recognition of conservation. A number of children recognised conservation in interior or displacement volume situations but not in all the volume situations, some other children conserved for liquid or solid substance but did not recognise conservation in both material situations, still other children recognised conservation of number in the flowers and jars or in the beads in beakers situations but not in both situations, and finally, a number of other children recognised conservation of area in potato plot on field situations but not in houses on field situations.

In length and area situations, differences in the particular transformations gave rise to differences in recognition of continuing equality. A number of children recognised continuing equality of length for sticks after they were staggered or put into Mueller Lyer arrowheads but they failed to recognise equality of length for transformations of strips of paper, some other children recognised continuing equality of length only in the staggered sticks situation and not in either the Mueller Lyer or paper strips length situations, a number of other children recognised continuing equality for transformations of 2 and 4 but not 12 and 20 houses on fields or for 2 but not 4, 12 and 20 houses on fields, still other children recognised equality of plot and field areas for 2 but not 4 piece transformations of plots on fields, and finally, some other children recognised equality for only the plot area and not the field area when the 2 piece transformations were made and not at all when the 4 piece transformations were made.

The following paragraphs give details of the situational differences found, first for recognition of conservation and then for recognition of continuing equality.

In the case of volume conservation, six children recognised conservation in both the interior and second displacement volume situations though not in the Piaget-type displacement situation, two children recognised conservation in both displacement situations but not in the interior volume situation, and two other children recognised conservation in the interior but not in either displacement volume situations. Thus, there was no evidence of a necessary interior-before-displacement volume conservation sequence; children were not usually found to recognise conservation of interior before displacement volume.

Conservation in the liquid substance situation was quite a few times recognised before conservation in the solid substance situation. Eight children conserved for liquid substance transformations but not for solid substance transformations. One child conserved for solid but not liquid substance.

Conservation of number in the flowers and jars situation was several times recognised before conservation in the beads in beakers situation. Five children conserved for flowers and jars transformations but not for beads in beakers. One child did the reverse.

Area conservation was quite a few times recognised in the plots on fields situation before it was recognised in the houses on fields situation. Nine children recognised conservation of plot and field areas but failed to recognise conservation in the houses on fields situation. No children recognised conservation in the houses on fields before plots on fields situations.

Equality without conservation of length was quite often recognised. Nine children recognised equality of length in the staggered sticks situation but failed to recognise equality or conservation of length in the paper strips and Mueller Lyer transformations. Four other children recognised equality of length in both the staggered sticks and Mueller Lyer situation but did not conserve for paper strip length. None of these thirteen children gave any clear explanation for their recognition of continuing equality and all failed to recognise the equality in the later length situation transformations. The Mueller Lyer transformation did not always have the effect expected; several children insisted the sticks looked the same length and made some perceptual but no conceptual judgments of equality of length.

Purely perceptual judgments of equality were also often made in the area situations. Fifty-five children recognised equality of area for transformations of 2 or 2 & 4 but not 12 & 20 houses on fields. Twenty-nine children recognised equality of area for 2 but not 4 piece transformations of plots. Of these twenty-nine, seventeen did not recognise equality of the fields, as opposed to plots, area for either the 2 or the 4 piece transformations. Less than a quarter of these eighty-four children gave any real explanation for the equality judgments they made. The children normally gave no explanation; they sometimes said "it just looks that way" or that they "just guessed". Their comments were usually quite sensible but were not justifications for conservation; they said, for example, "there's still a lotta grass in the middle" or "the cows can move around more". A few children's comments seemed to imply reversibility, for example, one child said "the houses are just moved" but he failed to recognise conservation when more, i.e. 12 & 20, houses were moved. Of the children who only failed to recognise conservation in the houses on fields situation, several appeared to recognise the identity of the houses or compensatory relations or the possibility of reversibility in the 2 and/or 4 house transformations, but this did not result in a recognition of area conservation in the 12 and 20 houses on field transformations. Thus, even though a number of children gave some explanation for equality judgments when the lesser transformations were made, they did not recognise conservation when the greater transformations were made. In other words, all eighty-four children failed to meet the criteria for area conservation because they failed to recognise continuing equality for <u>every</u> transformation, including the more extensive ones, and failed to give clear reasons for conservation when, for some transformations, they made correct perceptual judgments of equality.

Two points about the children's responses in the area situations remain to be mentioned. First, when children made perceptual judgments of equality of area in the houses on fields situation, they usually judged 2 and 4 house transformations similarly, i.e. most children recognised equality of area for 4 if they did for 2 though not 12 and 20 houses on field transformations. Second, when children made perceptual judgments of equality of area in the houses on fields situation, they often but not always also made perceptual judgments of equality of area in the plots on fields situation.

In the distance situation, <u>all</u> the children recognised the equality before and after the dividers were put between the objects. This was perhaps facilitated by the experimenter's pointing the direct path and citing the objects by name. The children understood the distance in question and considered object to object, not object to divider, going through, not over or around, the divider; several children, for example, said it was the "same far when you keep going through". Perceptual judgments may be all that were necessary in the distance situation; many children said that "it looks as far still" or "it's still a way" or "apart" or "not together" or "it's as out still". Often children just emphatically stated the fact that it was the "same going" or pointed and said that the objects were "there and there". Some children explained that the objects "haven't moved" or "haven't been put any nearer" or "can't go" or, even, "would have moved if it weren't the same". A few children suggested measuring to show the distance was the same. The children's explanations were unlike their explanations of conservation in the other attribute situations; the usual identity, reversibility, compensation arguments would be less appropriate in the distance situation.

Altogether, it was clear from the results of the pre-test that understanding of conservation did not develop in an all or none fashion. Children often recognised conservation for some but not other attributes, in some but not other situations, and for some but not other transformations. After recognising and giving reasons for conservation in the earlier situations, children failed to recognise conservation and the underlying similarity of the later situations.

There are a few final points to be mentioned in relation to the pre-test. It was found possible to test the children for conservation in the 14 situations during one session of approximately 30 minutes; but this was about the maximum possible for a single session. All the children were interested, co-operated willingly, andunderstood the questions. The children's actual explanations of their judgments revealed their understanding of conservation or lack thereof; some of these explanations are recorded below.

Examples of children's explanations for conservation judgments:

For several situations:

It was the same in the first place (before etc.)

They were the same before

They started out (off, etc.) the same

They were level before

I saw you made it from the same

You can do the same to the other one

(Demonstrations of reversibility without verbalisation of reasons)

You haven't pulled (moved, taken, chopped, poured, out, etc.) none off (away, out, etc.)

You haven't left any behind (out, etc.)

If it was different you would have took some off

You kept (took, collected, tipped in, put in, etc.) it all

It all came out

They look different (less etc.) but they're the same amount

You can measure one after the other the same

You can put it back (together, etc.) and measure it's the same

For number particularly:

There were two 6s in each before
There was one in each jar before
There were 6 (or 12, or 10) in before

You took one out of each and it will still be the same

There was one for each and they're still the same flowers and jars

I coun'd 'em the same as you put 'em in

I coun'd them and there wasn't another put in

For substance particularly:

The longness is the same as the roundness

It's the same heaviness (weight, etc.)

For length particularly:

It goes together straight

You didn't change the piece itself

It's the same amount - none is chopped off length

The sticks are the same length - it's the same sticks but not all the rest (in Mueller Lyer situations)

You can put the pieces together and measure the same

You can measure that to that (pointing)

For area particularly:

You can put the cuts back the same

You can cut the other the same now

They're the same houses just put in a different way (just put in different rows, etc.)

It's the same amount of houses and space

They're the same amount of measurement (pointing)

It's the same length there and there (pointing to two lengths & two widths)

It's the same length and wide

The cow can still go round (move between or in and around or in and out etc.) the houses the same this and this way (pointing length and breadth)

For weight particularly:

They felt the same weight before

It's the same size still and the same amount

One's more wider, other's more thicker

They'd weigh the same level if you try

For volume particularly:

The layers were equal

There are the same rooms in it

There are the same lots in each still

They are the same squares

There are no more bricks

The water can't go up unless you put more blocks in

Examples of children's explanations for nonconservation judgments:

For several situations:

They look more

You can tell by looking at 'em it's more

They're not the same shape

It's bigger (aloter, higher, longer, ahead, morer, up more, etc.)

There's more on

There's more there because there's less there (pointing to one and then other)

For number and substance particularly:

There's more 'cause it's in a bigger bowl (glass etc.)

For length particularly:

It's longer 'cause it's moved farther up

It's longer 'cause it's higher along

It's longer because it's more

One's longer 'cause the other's shorter

For area particularly:

There's more 'cause there's space on top for potatoes

You can fit more potatoes in because it's bigger

The plots aren't level any more

That plot's wider

Spread out houses take more space

There's littler (less, etc.) space 'cause there are houses in the middle now

There are a-loter houses crowded round so there's littler grass space

The houses are spaced out here so there's more space in the other

There aren't houses there so there's more space (pointing)

The houses are closer together (squashed in the corner etc.) so there's more space for the cow

The cow can run about more because the space isn't covered with houses

That group measures less space

For volume particularly:

There's more room in it because it's longer

You can fit more in it 'cause it's bigger

It's built up more

It will make the water rise more 'cause it's bigger

It will be heavier so it will make the water rise more

To conclude, analysing all the children's explanations and not just those quoted above, the type of reason most frequently given for conservation judgments was reversibility; identity-type reasons were the next most frequently given; and compensation explanations were rarely made. The most common explanation for conservation judgments was that it was the same before or that it could go back the same or even that the other could be put the same. An almost equally frequent explanation was that it was the same material, amount, length, weight, size, etc. or that nothing had been taken away or added. An external criterion such as absolute number, 6, 10, or 12, was often mentioned. Rarely were compensatory relationships cited.

A few children indicated reversibility but did not recognise conservation; for example, one nonconserver said "there's more room in the longer one but it was the same room when you started" and another said "there's more space now - it was level the same before". Similarly, a few children recognised identity but not conservation; for example, one child said "there's more room inside even so same rooms" and "the water will go down even so same amount". Likewise, a few children noted compensatory relations but did not recognise conservation; for example, one nonconserver said "there are more bricks along, but it's not as big up, but there's more room inside". Thus, recognition of prior equality or sameness of material or compensating dimensions did not necessitate conservation. Such recognition, however, may be an element in the gradual development of conservation and may provide evidence for conservation when full understanding does develop. Reversibility (particularly when the possibility of return to the original is suggested), or identity (particularly when the fact that nothing has been added or taken away is mentioned), or compensation (particularly when exact equivalence is indicated), when used as reasons in an argument for the necessity of conservation provide clear evidence of genuine understanding of conservation.

(ii) Teaching.

Fifty-one children, who had failed to recognise conservation for two or more attributes (nonconservers in all situations for those attributes), were divided into three groups matched as closely as possible for chronological age and IQ, and matched exactly for degree of initial understanding of conservation. Each group of seventeen children was given one of three different treatments. A T1 teaching group was given instruction on conservation as a general principle, a T2 teaching group was given instruction on the conservation of area, and a control group was given reading practice. In the T1 group, ten were boys, in the T2 group, twelve, and in the control group nine. The following table gives details of the matched groups of children.

		T1		T2		C		Range	
		CA	IQ	CA	IQ	CA	IQ	CA	IQ
Nonconservers:									
6 attrib situs area, vol, wt, len, subs & no.	1	11. 9	56	10.10	50	10. 6	51	1. 3	6
	2	13. 2	67	13. 4	63	13. 5	79	3	16
5 attrib situs area, vol, wt, len & subs	1	10.10	63	12. 5	69	11. 7	79	1. 7	16
	2	14. 0	57	12.11	61	12.11	66	1. 1	9
4 attrib situs area, vol, wt, len	1	11. 9	69	11.11	67	12. 2	55	5	14
3 attrib situs area, vol & wt	1	11. 2	74	10. 5	69	11. 6	64	1. 1	10
	2	11. 9	55	11. 9	59	11. 9	59	-	4
	3	13. 1	71	13. 2	66	12. 7	59	7	12
2 attrib situs area & vol	1	10. 7	60	10. 8	71	9. 5	57	1. 3	14
	2	11. 5	63	11. 6	70	10. 9	67	9	7
	3	11. 9	63	12. 3	77	12. 6	63	9	14
	4	12. 9	63	12. 6	73	13. 0	65	6	10
	5	13. 3	59	12. 9	72	13. 0	61	6	13
	6	14. 2	69	14. 9	75	14. 3	60	7	15
	7	14.10	74	14. 9	71	15. 1	64	4	10
	8	15. 4	68	15. 7	77	15. 6	67	3	10
	9	15. 5	57	16. 1	67	15. 7	62	8	10

The T1 group of children were given instruction designed to develop an understanding of conservation of quantity in a general sense, that is, instruction designed to develop a broad concept of conservation independent of particular attribute situations. The aim was to teach conservation as a general principle which would be applied in a wide range of attribute situations. In Investigations One, Two, and Three, conservation of particular attributes, weight or volume, had been taught and such conservation was found to generalise to one or two other attributes. Generalisation of conservation was indeed the aim of these prior experiments but the generalisation first sought was generalisation of conservation to different situations involving the one attribute taught. In the present experiment generalisation to various attribute situations was sought. The aim of the T1 teaching scheme was to teach conservation itself and not of any particular attribute, by using a variety of situations and without detailed discussion of the specific attributes conserved.

Although it may be unnecessary to discuss conservation in six attribute situations with children who already recognise conservation in some of the situations, the use of the same teaching scheme with every child in the T1 group in this experiment provided for investigation of the influence of different degrees of initial understanding, as well as for answering the question whether it is possible to teach conservation of quantity in a general sense and using a brief teaching scheme. Before being taught in an attribute situation, each child was given a chance to solve the conservation problem himself. This was done to reveal whether a child developed recognition of conservation during the course of the teaching.

The T2 group of children were given instruction designed to develop an understanding of area conservation. The aim was to teach conservation in Piaget-type area situations so that it would be generalised and recognised in unfamiliar as well as familiar situations. No other attribute situations were considered in teaching the T2 group. The same teaching was given to every child in the T2 group regardless of his initial understanding of conservation; none, of course, had previously recognised area conservation. The T2 teaching scheme was presented in order to find out if area conservation can be developed using teaching briefer than that which developed weight and volume conservation in the prior investigations, and whether such a taught concept of conservation will be generalised to other attribute situations.

The control group children were given no instruction on conservation but were seen by the experimenter for the same length of time as the children given instruction on conservation. The controls read to the experimenter from their classroom books and answered questions on their reading. This was done to ensure that all the children received the same amount of individual attention and knew the experimenter equally well by the time of the post-testing..

Five basic explanations for conservation and four types of experiences were used in teaching conservation to both T1 and T2 groups in this investigation. In the writer's prior experiments teaching conservation to educationally subnormal children, certain explanations seemed most meaningful for the children. Nonconservers had found the following types of explanations convincing: it is the same (material) all the time, nothing has been taken away or added, it looks different but really it is the same (material), one is (more this way) but the other is (more that way), you can put it back as it was before. Certain teaching methods likewise seemed most effective for such children; these included a combination of verbalisation with observation or manipulation or the use of an external criterion. These explanations and methods were selected as fundamental for both the T1 and T2 teaching schemes of this experiment. Though the content and emphasis of the teaching for the two groups of children were different, the types of explanations and methods used were basically similar.

The following table outlines the basic form of the teaching used for both T1 and T2 group children.

	meths			
	1	2	3	4
	Verbalisn (by E &/or S)	Observn (E dem)	Manipn (S act)	Extern. Criter (incl count'g, mark'g off etc)
explans 1. Same Mater'l (Iden)	x	x		
2. Noth - + (Iden)	x	x		x
3. Distin ap & real	x	x		x
4. Compens	x	x		
5. Revers	x		x	

The above form of teaching, i.e. basic explanations and methods, was given to the T1 group of children in six attribute situations. Only six of the fourteen pre-test situations were presented in teaching these T1 children; conservation in the distance situation was not included because the explanations and methods appropriate for all the other attribute situations are not appropriate in the distance situation and, in any case, here <u>all</u> the children had already recognised the equality. The above explanations and methods were also used with the T2 group of children but in area conservation situations only. In teaching these T2 children, the houses on fields as well as potato plot transformations were included.

The various explanations and methods were used in the teaching for both T1 and T2 group children in order to develop a fuller understanding of conservation and to provide for individual differences in the children's learning. Several explanations compose a case for conservation; no one reason provides final evidence in every attribute situation. The question of the basis for conservation is complex, but clearly, reversibility does not necessitate conservation (e.g. volume is not conserved though steam can be turned back to water), nor does identity necessitate conservation (e.g. the length of a rubber band changes though it is still the same rubber band). Nor, indeed, does recognition of prior equality or sameness of material guarantee recognition of conservation. Likewise, compensation may be recognised perceptually without necessitating conservation. No one of these reasons appeared to provide sufficient explanation for conservation. Furthermore, in teaching educationally subnormal children it had often been clear that some children did not grasp the significance of a particular reason for conservation but found another particularly convincing. Different explanations and methods helped different children to a different extent. In addition, educationally subnormal children were rarely fully convinced by just one explanation. A child might accept a reason for conservation on a teacher's authority, but to develop any real understanding a fuller explanation is necessary. The aim of the teaching in this investigation was to help all the children to appreciate the grounds for conservation judgments, to look for evidence of conservation, to develop relevant arguments for conservation and not merely to give conservation judgments for a particular reason.

In teaching the T1 group children, one material situation out of each pre-test pair for an attribute was used. (All attributes except distance were included; distance was excluded for reasons discussed earlier.) Two or three transformations of the material were made in each situation. The particular situations used with the T1 group were chosen so as to give more varied experience and experience in clearly distinct attribute situations. The bunching and spreading number situation was used rather than the beads in beakers situation which would have been too similar to the liquid substance situation. The liquid substance situation was presented rather than the plasticine substance situation because it was less like the weight situation where plasticine was used. Plasticine was used to teach conservation in the weight situation because relative weight could be more clearly distinguished and transformations more easily made and reversed with plasticine than with cotton wool. Sticks were used in the length situation as they provided a material situation less like the potato plots area situation. For area the potato plots situation was chosen as more clearly a 2D area situation. Similarly, the metal blocks displacement volume situation was used as it was more clearly a volume situation, and one in which volume conservation could be easily recorded or measured. In the number conservation situation, the T1 group children matched and counted flowers and jars; a small as well as larger number of objects was used. In the substance conservation situation, they did not use any form of measurement but just manipulated reversibility as was done in every attribute situation. In the length conservation situation, they marked the sticks off on a common longer stick. In the area conservation situation, they again did not use any external criterion but did manipulate reversibility. In the weight conservation situation also they did not use a measure but manipulated reversibility. Finally, in the volume conservation situations they marked off the water level displacements in a common container.

When the T2 group children were given instruction, the two area situations of the pre-test were used and three transformations were made in each situation. The T2 group in the area situations did all that the T1 group did for area and in addition used an external criterion which the T1 group did not use. The T2 group children covered the potato plots and fields with transparent perspex grids and counted the number of rectangles covering the different transformations. In the houses area situation, included in teaching the T2 but not T1 group children, no external criterion was used. The houses were not counted in the different transformations because conservation of the area of the fields as distinct from conservation of number was sought.

Each child, in both T1 and T2 teaching groups, was instructed individually for one session of approximately twenty minutes. Although the teaching procedure was flexible and was adapted to the individual child, it was kept within the standard limits for each group and included the set explanations and experiences. The five standard explanations were elicited from or given to every child; for the T1 group, these explanations were made for two transformations in the number, substance, length, and weight situations and for three transformations in the area and volume situations, and for the T2 group, for three transformations in each of the two area situations. The four standard experiences were also given to every child; the children observed the same type of demonstrations, manipulated reversibility, and used an external criterion in comparing material before and after transformation.

Two or three transformations only were made for each material so as to provide varied experience without exhausting the children's attention. Care was taken not to include too many transformations, material situations, explanations, or experiences and to bring out the underlying general principle of conservation in the different attribute situations. The transformations for the T1 group children included ten flowers bunched and five spread, orange drink poured into a petri dish and four beakers, 10cm sticks staggered and 20cm sticks put into Mueller Lyer arrowheads, plot and field area transformations, pancake and ten piece plasticine transformations, and 6x6x1 and 4x3x3-in-four-parts metal block transformations. For the T2 group, 20 and 4 and 12 house transformations as well as plot and field area transformations were presented. No exceptions to conservation were introduced as this would unnecessarily complicate the teaching for educationally subnormal children. Inequality situations were not used in teaching either; these situations were kept as a test for generalisation of conservation in the post-testing.

The T1 group children still gave nonconservation answers for the first transformations presented in attribute situations in which they had failed to recognise conservation when pre-tested. All of the T2 group children likewise gave nonconservation answers for the first conservation problems presented in teaching them area conservation. Thus, there had been no change in the children's understanding of conservation between pre-test and teaching and, in addition, for the T1 group, discussion of conservation in attribute situations where they already recognised conservation did not lead to immediate recognition of conservation in attribute situations where they had not previously recognised conservation.

Understanding of conservation only developed gradually during the course of the teaching. Individual differences were noticeable and the influence of degree of prior understanding of conservation was sometimes apparent, but few children generalised their developing concept of conservation until conservation had been explained and experienced in several situations. If a child did generalise to a later situation or transformation he normally recognised conservation for some but not necessarily all of the later transformations. In other words, it was clear that understanding of conservation did not develop in an all or none manner.

The explanations for conservation most frequently accepted and used by the children were first, that nothing had been taken away or added (mentioned by twenty children), second, that it was the same before and could be made back the same again (mentioned by thirteen children), and third, that it was the same material (mentioned by five children). Compensating relations were mentioned by three children and one child suggested measuring to prove the continuing equality. Several children who were slow to put their reasons into words demonstrated reversibility. Most children gave several explanations for their conservation judgments and expressed their reasons in their own words. No children repeated verbatim reasons used in the teaching.

By the end of the T1 or T2 teaching session, thirty out of the thirty-four children given instruction had developed an understanding of conservation. Four children, who in the pre-test failed to recognise conservation in six attribute situations (i.e. nonconservers of number as well as substance, length, area, weight, and volume) did not develop understanding of conservation during the course of the teaching. These four who had shown no evidence of a concept of conservation in any pre-test situation did not learn to recognise conservation after being instructed according to the T1 or T2 teaching scheme. Both of these teaching schemes, however, were briefer than prior teaching schemes effective in developing understanding of conservation of weight and of volume in ESN children.

(iii) <u>Post-testing</u>.

Both the T1 and T2 teaching groups were given the same post-test one week and then again two months after they had been given instruction. Each child was tested alone for about 25 minutes. The standard post-test included 13 of the pre-test situations plus 7 new material situations and 6 conservation of inequality situations. Seven of the 13 pre-test situations were those in which conservation had been taught to the T1 group, while the other 6 were familiar only from the pre-testing and had not been included in their teaching. Only two of the pre-test situations had been used in teaching the T2 group. In addition to the situations from the pre-test, new material situations were introduced for the types of situations in which conservation had been taught, and likewise, conservation of inequality situations were included instead of the straight, not involving conservation, inequality situations of the pre-test. One transformation only was made for each situation from the pre-test as well as for each new material and inequality situation. The actual wording of the post-test problems was similar to that of the pre-test. (Detailed description of the post-testing procedure is given in the chapter appendix).

The order of the situations in the post-test was similar but not identical to that in the pre-test. That is, the sequence of attributes - number, substance, length, area, weight, volume - was similar, but for each attribute the situation in which conservation had been taught was presented first and this meant reversing the pre-test order for the number, area, and volume situations. In addition, the new material situation for each attribute was presented after the situation in which conservation had been taught and then the pre-test situation in which conservation had not been taught followed by the conservation of inequality situation.

For number, cubes, new material, were spread after the flowers were bunched; an unprovoked correspondence situation was included in addition to the provoked correspondence situation. Next, the 12-beads-into-the-wide-container pre-test situation was presented and then a conservation of inequality situation involving 12 and 6 beads in which the 6 were transferred into a tall thin container. For substance, sand, new material, was transferred into a large flask after the orange drink was poured into the low container. The plasticine-into-sausage pre-test situation was next presented and then a conservation of inequality situation in which the larger of two plasticine balls was cut into 7 pieces. For length, one of two wires, new material, was transformed into an arc after the sticks were staggered. Next, the paper-strip-cut-to-form-the-zigzag pre-test situation was presented and then a conservation of inequality situation in which the longer of two strips was cut to form a right-angle. For area, two vertical red felt-coated cardboard backgrounds each with a blue felt circle on it, new material, were presented and one background, pre-cut, transformed into a diamond shape. This was done after the horizontal 4 piece potato plot transformation was made. The 20-houses-rearranged-on-a-field pre-test situation was next presented and then a conservation of inequality situation involving 20 and 12 houses on fields in which the 12 were spread farther apart. For weight, one of a pair of meccano lattices, new material, was collapsed after the ball of plasticine was flattened into a pancake. Next, the cotton-wool-rolled-out pre-test situation was presented and then a plasticine, and not cotton-wool, conservation of inequality situation in which the larger of two plasticine balls was cut into 10 pieces. Finally, for volume, equal volume differentially weighted plasticine balls, new material, were used after the metal blocks. In the Piaget-type displacement situations, the transformation of a ball of plasticine so that part would be in each corner of the dish was presented for consideration after the metal blocks spread along the bottom of the dish transformation. In the second type of displacement situations, the actual transformation of one of the two plasticine balls into a zigzag was carried out after the metal blocks were put into the 6x6x1 transformation. Next, the interior volume wooden-blocks-into-the-12x3x1-building pre-test situation was presented and then a conservation of inequality situation in which the smaller of two buildings was made 12x2x1. No distance situations were included in the post-test because <u>all</u> the children had recognised the continuing equality in those situations in the pre-test and they had been deliberately omitted from the teaching.

All 26 post-test situations were presented to all the children given instruction whether or not they had recognised conservation in some of the situations when pre-tested. This was done in order to reveal any differences in the children's responses after teaching due to their different degrees of initial understanding and to reveal any influence of the teaching on the children's explanations of conservation. Generalisation of the taught concept of conservation was tested using all the new material situations and inequality situations as well as untaught pre-test situations for both the T1 and T2 group children. It was necessary to introduce these varied situations to test for generalisation for the T1 group children who had been taught conservation in 6 attribute situations. Certain of these situations were not necessary in testing the T2 group children who had been taught conservation in area situations only. But in order that any differences resulting from different teaching experiences might be revealed both T1 and T2 groups were post-tested in exactly the same way.

Four transformations were made to test conservation of each of the 5 attributes: number, substance, length, area, and weight; 6 were included for volume. One transformation in each of 4 or 6 material situations for an attribute was sufficient for the assessment of a child's understanding. In case of any ambiguity in a child's response, extra transformations, of course, could have been included in any situation. The influence of differences in the particular transformations made had been recorded in the pre-test; the transformations made for the post-test situations were those least likely to give rise to correct answers for purely perceptual rather than conservation conceptual reasons.

All transformations were made in full view of the children; gestures were used to clarify the questions. No negative options were given in the questioning, i.e. the questions were not worded 'same or different'. This might make it more likely that children would give conservation answers in the equality situations but it might likewise make it less likely that children would recognise inequality and conservation in the inequality situations. Non-committal remarks only were made after the children's responses (e.g. 'I see').

The post-test results for the T1 and T2 teaching groups were similar. Fifteen T1 and fifteen T2 group children developed understanding of conservation. All except two children in each teaching group learned to recognise conservation and did so in every situation of the post-test; the children who developed understanding gave clear reasons for all their conservation judgments. Only the children who had failed to recognise conservation of number as well as all 5 other attributes on the pre-test failed to develop understanding of conservation after being given either the T1 or T2 teaching scheme. In other words, thirty children, given one of the two teaching schemes, made conservation judgments throughout the post-test. These children, despite differences in their initial understanding of conservation, all gave conservation judgments on all the familiar, unfamiliar, and inequality transformations of the post-test. Four children, also given one of the two teaching schemes, however, developed no understanding of conservation. These children remained nonconservers of all 6 attributes: number, substance, length, area, weight, and volume.

The fifteen T1 group children developed a generalised understanding of conservation evidenced in the new material and inequality as well as untaught pre-test situations and the fifteen T2 group children generalised their understanding of conservation from the area to other attribute situations as well as to new material and inequality situations. Children in both groups who started with different degrees of initial understanding of conservation understood and considered the different attributes in question and generalised their taught concepts of conservation for appropriate reasons. In the T2 group, the two children who had been nonconservers of substance, length, area, weight and volume generalised their taught concept of conservation of area to the other 4 attributes, the child who had been a nonconserver of length, area, weight and volume generalised her new understanding to 3 other attributes, the three nonconservers of area, weight and volume generalised to the 2 attributes not taught, and the nine nonconservers of area and volume also generalised their taught concept of conservation to the untaught volume situations.

Although there were great individual differences in the children's explanations for their conservation judgments, i.e. differences in fluency, clarity, particular expression of reasons etc., the reasons the children gave could be identified as basically 'nothing has been added or taken away' and 'same material' identity-type reasons, reversibility-type reasons, and compensation-type reasons. The reasons given by the children were of course influenced by the teaching but the frequency with which the different types of reasons were mentioned may indicate the relative effectiveness of the different explanations in the teaching. The fact that nothing had been added or taken away was given as a reason for conservation by twenty-six children on both their first and second post-tests. (The fact that nothing had been taken away was twelve times mentioned alone whereas the fact that nothing had been added was only once mentioned alone). This 'quantitative' form of identity reason was by far the most frequent reason given by the children taught in this investigation. The next most frequently mentioned reason was that of reversibility. Eight children on the first post-test and ten children on the second gave this type of reason for conservation. Compensation type reasons were given by two children on the first and five children on the second post-test. The sameness of the material, the 'qualitative' form of identity reason, was mentioned as a reason for conservation by two children on the first post-test and three on the second.

The reasons the children gave on the post-tests were similar to those they had given during the teaching session. Twenty-three children mentioned the same reason or reasons in justification of their conservation judgments in the post-tests as they had in the teaching; five children gave more reasons on the post-tests and two gave fewer. The relative frequency of the different types of reasons was similar.

The reasons the individual children gave on the first and second post-tests were likewise similar; each child's identity or reversibility or compensation reasons were just as clearly and fully explained on the second as on the first post-test. The relative frequency of the different types of reasons was similar and every child mentioned some of the same reasons on both post-tests, but seven children gave considerably more reasons on the second post-test and two children gave fewer.

More than a verbal formula was learned. Although the children's reasons could be described as identity or reversibility or compensation type reasons, the children's actual explanations of their conservation judgments were expressed in varied and often very full terms appropriate to the particular situations and transformations. There were differences both between different children's explanations and within any one child's explanations. Some examples of the different ways children expressed reasons classifiable as identity, reversibility or compensation type are recorded below.

Examples of 'quantitative' identity type reasons for conservation of equality:

You haven't took (moved, poured, sawed, cut, pulled etc.) none off it.

There isn't any left behind (out, etc.).

You haven't taken no beads (plasticine, plot, grass, blocks etc.) away.

If you took any blocks (plasticine) away the water wouldn't rise the same 'cause there'd be less blocks (plasticine).

There isn't none added to it.

You haven't gained any.

You haven't put none (no pieces, no more etc.) to it (on it etc.).

If you add more blocks (plasticine) on, the water will rise over the top.

There's no more and no less to it.

If you added some or took some off it would be different.

Examples of 'qualitative' identity type reasons for conservation of equality:

It's still the same flowers and jars (brown, squares etc.).

Examples of reversibility type reasons for conservation of equality:

It was the same equal when you started.

They were the same like that (pointing to comparison object).

They were the same in there (pointing to original containers).

There was one for each before.

I counted them thesame before.

It came the same level before.

It's just unstraightened, it was the same, it's the same along.

It was the same heavy when it was rolled up too.

It puts back the same.

You can make it back (demonstrating reversibility to same).

They move (tip etc.) back the same.

It rolls into a ball again.

It puts (folds, straightens etc.) together the same length.

You can move the other the same.

If you do the same to the other it will look the same.

You can bunch (roll etc.) the other like that (pointing to transformed object).

Examples of compensation type reasons for conservation of equality:

That one's as longer as the other one's fatter (demonstrating compensation relations).

The cow who goes round the outside gets the same equal as the other cow inside.

In addition to the above reasons for conservation of equality, many children also suggested an external criterion for empirical evidence of conservation.

You can count they are the same.

You can stand them up and measure to show they're the same.

Straightening it out will show it's the same beside the other.

Put 'em in the water to show they make it rise the same height.

The appropriateness of the children's different explanations of conservation in the <u>in</u>equality situations is further evidence of the extent of their understanding.

There's more in this one still - none is taken away from it.

There's less in the other one still - none is added to it.

You haven't took (moved etc.) none off from the more one (where morer etc.).

You'd have to take some off (away etc.) to make it same as the little one.

You haven't put none on (added none to etc) the one littler before.

You'd need to add some to the littler one to make it the same.

There's still more space here - you haven't took any houses off the other one.

You've still only got 12 houses on it and more houses on the other one-you haven't added back any houses to it so it's got more space still.

They were different (not the same etc) before.

There was more in that one before.

This one was less when you started.

The other didn't have as many before so this still has more.

There were 12 in one and 6 in the other before.

They weren't cut the same length at the start.

It weighed better before.

It was more and still is (demonstrating reversibility).

It wouldn't be the same if you made it back.

It puts back much more.

You'll see there's more in if you put it back in the other.

It's not the same because you can't put it back the same.

It won't roll back the same.

It puts straight (together etc) still longer.

It goes back heaviest.

If you moved the top floor of the bigger one it still wouldn't measure little same as the less one.

Clearly, the children had learned more than a mere rote response. Even where a child kept to one type of reason for conservation, the way that was expressed varied greatly (e.g. none are added on, no more is poured in, nothing is cut off, you didn't take none off, none of it is gone away, you didn't add anything to the littler one, the bigger one hasn't had any taken from it, etc.). Most of the children gave more than one type of reason for conservation judgments and gave reasons most appropriate for particular situations (e.g. identity type reasons rather than reversibility type reasons in the Piaget displacement situations where no actual transformation is reversible).

The children's conservation judgments were not automatic. They attended to the situation presented and recalled relevant considerationsbut did not always immediately give conservation answers. Several children hesitated in the houses on fields area situation (e.g. just a minute - yes - you haven't taken any green space away, no - no - I know - it puts back the same so it must be the same amount of grass space now) and in the plasticine displacement volume situation as they distinguished considerations of volume from weight (e.g. no - yes - yes - they still make the water rise the same but they still weigh different - they take up the same amount of room - you haven't took none off).

The children's explanations, some of which are quoted above, reveal their genuine understanding of conservation. The examples given so far indicate the diversity in their expression of identity, reversibility, and compensation type reasons. An individual child's explanations when taken in series for all the post-test situations provide compelling evidence of the fullness of the developed understanding of conservation.

One child gave the following reasons for her conservation judgments:

> You haven't took none away, it's the same 12, the 6 are still less, it tips back the same, it was the same before, it puts into a ball again, it puts back bigger still, it puts together the same length, it folds back together, it's still the same brown pieces, it puts back the same, if the cow goes round the outside he gets the same, you can move the other the same, if you took some away it would be lighter, if you put it in the water it will show how it rises the same, if you took some away the water would rise less, you took some away so there's less room inside.

Another child gave the following reasons:

> It's the same flowers and jars, you can bunch the others

the same, it's the same blocks, put in the other it comes the same height, you took some away, when you started it was the same, you haven't taken none, you haven't added none, it was the same before, it's unstraightened but it's the same as it puts straight the same, it will come the same if you do the same to the other, it puts straight longer, the grass is in and around but it's the same altogether, you can do the same to both, it was the same when you started, it puts back the same, it puts back more, it was more when you started and you haven't taken none away, it's the same ball, it's the same squares.

One boy included the following reasons for conservation:

You haven't took none away and you haven't added none, you can put them back in the same line, if you put a bead in you'd have one over, it's higher but the other's rounder, you can tip it back to come the same level, it's the same plasticine, you can make the other the same way, it was the same at the start, it'll bend back the same again, put them all together and measure it the same, it puts back bigger still, it's the same metal squares and the same heaviness, it was the same block at first and you haven't moved none off, you must have took some away from one and not from the other before.

Another child mentioned the following:

There are 10 (or 12) in each like before, the taller thinner one still has 6 and less, one's fatter but the other's taller and the orange tips back the same, it's the same heavier still, put it together and it measures the same, it still measures smaller, it puts back the same see (demonstrating reversibility), it's longer but the other's fatter, it's taller - the other's wider, you can make it the same by taking houses off the other field, you'll see it's the same if you weigh them on a scale, it closes back the same, you can put both in and measure each one the same, if you put any on the water would go up, you haven't took any water away, you haven't added or taken away any bricks.

Finally, one child explained in the following ways:

> You haven't added or taken away any, they add up to the same number, more was in one before, you haven't drunk any to make it less, you haven't cut it in half - if you had it would have been half as much, you haven't cut any off, I have to think that one out - all you've done is make it look different - it still is the same 'cause you haven't added or took any away - you haven't took none off, you haven't took the fourth piece away to make more space for grass, if you just glance it looks different but if you have a good look you know it's the same 'cause you haven't taken any parts away, it's higher but the other's longer, it's still more - you must have took some away from one and not from the other before.

The four children who had failed to recognise conservation of number as well as substance, length, area, weight, and volume on the pre-test and who did not develop understanding of conservation after being given either the T1 or T2 group teaching scheme generally made consistent though incorrect judgments on the post-tests. They attended to the different problem situations, understood and used appropriately terms such as same, more etc. in making perceptual choices, gave coherent and not totally irrelevant explanations for their judgments which were more than just random guesses, but they made no conservation judgments. They remained nonconservers throughout both post-tests.

In certain post-test situations some of these children recognised the continuing equality or inequality; where they did, they gave no clear arguments justifying conservation rather they merely described perceptual differences. The children sometimes re-counted for the same number after the transformations in the number conservation situations. (They sometimes also re-counted incorrectly). In the inequality situations for number, substance, length and weight, the children sometimes recognised the continuing inequality on a purely perceptual basis; they gave no reasonsfor conservation and failed to recognise conservation in all the equality and other inequality situations afterwards. None of the four children recognised conservation in the area and volume inequality situations; the area and volume inequality transformations most effectively revealed perceptual (as distinct from conservation conceptual) judgments. In these two inequality situations the real inequality was strongly contradicted by perceptual appearances and all four children chose the field with 20 houses unspread as having more space than the field with 12 houses spread out and then the 12x2x1 building as having more room inside than the 6x3x2 building.

Each of the four children seemed to have some particular basis for his or her judgments. The children seemed to focus on some aspect or aspects in making their choices, but what it was, or they were, was not always clear. One child made almost exactly the same perceptual choices on her second as on her first post-test. For over half the transformations on both post-tests she based her judgments of more on global 'compactness' (e.g. she said it was more because it was "bunched, rounder, squarer"). Another child less often made the same choices on both post-tests; in 6 of the 26 transformations he chose a different portion as greater in the second post-test. It was not clear what he was basing his judgments on; sometimes he gave clear explanations (e.g. "'cause it looks alotter, 'cause it's longer like two rooms, the water'll go down 'cause it's not so much plasticine") but often his explanations were unclear (e.g. "it looks strange, the other's all right, 'cause it's like that"). A third child made almost exactly the same perceptual choices on the two post-tests. She based her judgments of more on an increase in any one dimension (e.g. she said there was more in the wider, the taller, the longer, the straighter etc. because "it's got more beads, plasticine, bricks etc").

The fourth child less often made the same choices in both post-tests; about half of his choices were the same. Where his judgments were different he chose as more the one 'extended or spread' vertically or horizontally, where his judgments were the same he had chosen the 'extended or spread' portion before (e.g. he chose as greater the tube where the beads were higher, the plasticine sausage, the unbent uncut strip, the wooden 12x3x1 and 12x2x1 buildings etc.). None of the four children chose exclusively either the original or the transformed portion.

The post-test results show that educationally subnormal children can be effectively taught conservation in a general sense and conservation of area so that it is generalised to other attributes. This can be done using the quite brief teaching schemes of this experiment regardless of the children's initial degree of understanding of conservation, except in the case of children who fail to recognise conservation of number as well as substance, length, weight, area and volume. Children who exhibit no understanding of conservation in any of the 6 attribute situations may learn from fuller teaching than that given in this experiment. (This possibility was studied in a subsequent investigation, Investigation Five).

There were no differences between the T1 and T2 group children's developed understanding of conservation. Both groups had been given similar explanations and experiences of conservation but in a different number of situations; T1 group children were taught using 6 attribute situations and T2 group children using 2 area situations. Where fewer situations were used more intensive teaching was given; children taught conservation in area situations only were given more experiences in those particular situations than were the children given explanations and experiences in more different attribute situations.

Thirty children developed a durable and generalised understanding of conservation. When these children were post-tested after two months as well as after one week they recognised and gave reasons for conservation in all 26 post-test situations, only 2 of which had been familiar to the T2 group children from their teaching and only 7 of which had been familiar to the T1 group children from their teaching. (The four nonconservers of all 6 attributes remained unchanged over the time). That the thirty children who learned to recognise conservation had developed generalised understanding, and not just a specific learned response, was evidenced in their responses in the unfamiliar situations. Genuine understanding and extensive generalisation of conservation was revealed, particularly in the inequality situations. The children did not give the same responses to any and every situation; they gave clear and appropriate reasons for every judgment they made.

On the repeat pre-test given to the control group children when the experimental groups did their second post-test, all seventeen controls gave nonconservation judgments still in every situation where they had when originally pre-tested; the explanations they gave for their judgments were similar to those they had originally given. No control group children developed conservation of any new attribute during the 2 months between the original and the repeat pre-tests; there was no spontaneous development altering any child's recognition or non-recognition of conservation of the 7 different attributes. All seventeen control group children gave almost exactly the same responses in the original and repeat pre-test situations; individual children gave reasons for conservation judgments and non-conservation choices similar to those they had given before. In certain situations there were minor variations in some children's responses. In the houses-on-fields area situations some nonconservers altered their perceptual judgments. Three children recognised the continuing equality of space for the 2 or 2 & 4 but not 12 & 20 houses transformations on the repeat but not on the original pre-test; they gave no reasons for conservation and merely said "cause it looks wide the same", "it looks the same about" or "cause it looks the same". Three other children who had originally recognised the equality of space for 2 or 2 & 4 but not 12 & 20 houses transformations did not recognise the equality on the repeat pre-test. In the plots-on-fields area situations, two nonconservers recognised the continuing equality of brown space when the 2 piece plot was transformed but not when the 4 piece plot was used; in neither situation was conservation of green space recognised nor were any reasons for conservation given. When they recognised the equality of space for the 2 piece transformation in the repeat pre-test where they had not done in the original pre-test, the children merely said "the brown looks the same - the green doesn't" or "cause it looks straight". In the wooden blocks interior volume situation two nonconservers chose a different portion as greater and in the metal blocks Piaget-type displacement volume situation three other nonconservers altered their choice of greater portion. While there were these minor changes in some children's perceptual judgments or choices, the children's conservation and nonconservation judgments remained the same on the repeat as on the original pre-tests. There were no changes in the children's understanding of conservation of the different attributes during the course of 2 months.

III DISCUSSION

The investigation answered several questions and raised others. The pre-testing revealed a sequence in the development of conservation of multiple attributes and also the influence of particular situations or transformationson children's conservation and nonconservation judgments. Why there should be such a sequence and such situational differences are questions to be considered later in the discussion. The teaching and post-testing showed that the varied explanations and experiences given, though brief, are effective in developing conservation in a general sense and conservation of area so that it is generalised to other attributes. Exactly which aspect of the teaching was the most effective was not determined. Individual children's degree of initial understanding was found in some cases to influence the effectiveness of the brief teaching given. Whether an understanding of conservation can be developed in educationally subnormal children who fail to recognise conservation in the number as well as the other attribute situations of the pre-test remained to be further investigated. This was done in Investigation Five.

The first question answered in this investigation was that of a sequence in the development of understanding of conservation. Understanding of conservation in the substance situations was found to be evidenced before understanding in the weight situations which was found before understanding in the volume situations, as had been found in the writer's prior investigations with educationally subnormal children. Using the criterion of recognition or nonrecognition in <u>all</u> the situations for any one attribute, it can be said that twenty children in this investigation (like seven in Investigation Two and two in Investigation Three) recognised and gave reasons for conservation of substance but not weight and volume; and thirty-one children in this investigation (like eleven in Investigation Two and ten in Investigation Three) recognised and gave reasons for conservation of substance and weight but not volume. It can also be said, using the above criterion which excludes children who evidence conservation in some but not other situations for an attribute, that no child in this investigation or in Investigation Three and only one child in Investigation Two was an exception and recognised conservation of an attribute later in the sequence substance-weight-volume but not conservation of a prior attribute. (See the table at the end of the chapter appendix for the numbers when different criteria are used). The sequence conservation of substance-before-weight-before-volume was clear; the results in pre-testing these educationally subnormal children are in line with Piaget's general findings on the sequential development of these conservation concepts.

A further sequence in the development of understanding of conservation, conservation of number-before-substance and length-before-weight-before-volume and area, was revealed in this investigation, where children were pre-tested in more than the 3 attribute situations of the prior investigations. This more extensive sequence needs further study. Under the conditions of the pre-testing in the present investigation, equality in the distance situation was the earliest recognised, conservation of number next, then conservation of substance perhaps slightly before that of length, conservation of weight after that, and then conservation of volume slightly before conservation of area. The details of this sequence were less clear and material and transformational differences (to be discussed later) complicated the picture, but the basic order, which was quite clear, differed from that found by Piaget. Piaget has found conservation of distance, substance, length, area, and interior volume to arise at about the same time as each other and after conservation of number but before conservation of weight. He has found conservation of displacement volume to arise later than conservation of all these other attributes. Not all other investigators have found conservation to arise in the order discovered by Piaget. Goldschmid (1967), for example, reported a very different sequence: conservation of substance (plasticine)-number (bunched and spread and beads in beakers) - continuous quantity (substance liquid in beakers) - two dimensional space (area flat shapes) - discontinuous quantity (substance corn grains in beakers) - weight (plasticine) - area (fields and barns) - length (sticks staggered and in Mueller Lyer arrowheads) - three dimensional space (volume blocks building) - distance (movement along tracks and screens between objects). The sequence found in the present investigation differed from Goldschmid's as well as from Piaget's. While all three investigators revealed the sequence substance-before-weight-before-volume they differed on the order in which conservation of the other attributes was recognised.

What is important to recognise in relation to the different findings is that the exact presentation of the problems, as well as the problems themselves, and the criteria used in classifying answers as conservation or nonconservation influence the sequence found. In the case of distance, for example, pointing the distance, clarifying the question, in presenting the distance problem probably facilitated its solution in the present investigation. The particular problems used by Goldschmid (1967), which included movement along 2 different tracks and not only Piaget's distance problem putting screens between two objects, probably gave rise to the much later recognition of distance conservation that he found. The importance of situational differences in influencing the sequence found can be affirmed without going into the detailed conditions for the number, length, area as well as distance problems and the criteria for conservation/nonconservation used in the different investigations.

Why there sho ld be the distance-number-substance & length-weight-volume & area attribute sequence found in the present investigation of the children's understanding of conservation is not a simple question. The particular attribute considered, the language (the wording of the question) as well as the physical situation (material and transformation) together determine the difficulty of the conservation problem for the children.

In general, the complexity and familarity of the subject matter of the conservation problems may be said to explain the differences in difficulty. The fact that conservation of one attribute is recognised before conservation of another does not necessarily mean that conservation of the former is integral to conservation of the latter; it may just be a simpler problem. The sequence found is not entirely logically interrelated, for example, conservation of number is not necessary to conservation of length (in fact the two can be in opposition in the same situation) nor is conservation of length or number necessary to conservation of weight etc. Indeed it might be argued that conservation of one attribute need not precede conservation of another, rather certain situations and questions may be more difficult than others; it might even be possible to so change the situations and questions that the sequence of attributes would be altered. The sequence, in part, may be simply one of problems differing in complexity. Familiarity as well as complexity is an important consideration in explaining the general order of difficulty; the influence of experience, and probably of schooling, is important. These children would be taught to count before they would be taught to measure length, before they would be taught to use a balance in weighing, before (if at all) they would be taught any arithmetic calculation of volume or area. Such teaching in addition to everyday experiences may influence the children's responses in the conservation situations.

It is difficult to determine in detail why the children recognised invariance in relation to number before substance and length before weight before volume and area. (As discussed elsewhere, distance does not fit into this conservation sequence). Considering first volume and area, apparently the most difficult for the children, it might be argued that the questions of room and space involve consideration of multiple dimensions and likewise call upon information from more than a single sense. In addition the words room and space are to a degree ambiguous and volume and area in reality are less easily demonstrated as well as less simply experienced than are the other attributes. Volume and area are less easily measured than the other attributes; there is no simple concrete criterion for sameness of volume or area. Moreover, a question of sameness in relation to room and space may rightly include consideration of shape; shape, in practice, may affect the room and space available.

The children found the area houses situation the most difficult of all, perhaps because of the complexity of the transformations, the multiple movements of multiple pieces, and perhaps because the word space may imply emptiness. It was confirmed that the object the children were considering (e.g. cow) was not being imagined as larger than the space betwen the houses after these were scattered throughout the field, in which case the space free for it would, in fact, have been less than before because parts of the space would be physically inaccessible to the cow.

Volume conservation may be easier than area conservation because three-dimensional considerations may be more familiar to the children than two-dimensional considerations; volume corresponds with the physical structure of everyday objects while area is more of an abstraction from objects and actions. Children may have more experience filling and fitting in containers than covering surfaces; and though the mathematical calculation of area is simpler than that of volume, area as an attribute may be more abstract than volume.

Conservation in the weight situations was more easily recognised than conservation in the volume or area situations. This may be because the attribute of weight is more directly experienced in everyday life, is less abstract a consideration than volume or area, and is more simply measured. The weight conservation question is unambiguous and weight is more easily abstracted from shape than room or space are.

Conservation in the length situations was recognised more easily than conservation in the weight, volume and area situations perhaps because length varies along a single dimension, is directly visually experienced, is more simply measured than weight, volume or area, and questions concerning its conservation are neither ambiguous nor abstract.

Substance conservation, i.e. conservation of 'amount' not mass in the physicist's sense, was recognised early. This may be because simply the global identity of the shares need be considered; the concrete objects themselves, as wholes, rather than abstract qualities or aspects of the objects are in question. The question of 'amount' or 'fair shares' is unambiguous, directly experienced and a familiar consideration for the children.

Recognition of conservation in the number situations preceded that in the substance, length, weight, volume and area situations perhaps because equality of discontinuous amount is most easily verified. Counting provides a simple and much practiced external criterion.

Thus, various factors can be seen to interact to influence the sequence or order of difficulty found within the range of conservation tasks presented in this investigation. The different degrees of difficulty of the conservation problems, as evidenced in the children's gradually developing recognition of conservation, may be a result of the interaction of many factors which include the following: the complexity of the language and of the transformations, the familiarity of the situations and of the attributes under consideration, the relative abstractness/concreteness of the problem etc. No one factor is likely to be the all important determinant and it would be difficult to decide the relative influence of, for example, language and the physical situation or complexity and familiarity.

The influence of particular situations or transformations was the second question studied in this investigation. Situational differences were found to be important in area, distance, length, volume, number and substance problems.

The findings on conservation in area situations differed from Piaget's. There was no evidence either of the interior before complementary area conservation order or of the houses before plots on fields conservation order that Piaget found. In the present investigation it was found that in the plots on fields area situations perceptual judgments of equality were often made without an understanding of conservation, but it was <u>not</u> found that conservation of interior area was understood before conservation of complementary area. In other words, situational differences were found to give rise to perceptual recognition of <u>equality</u> in some interior area situations with no recognition of <u>conservation</u> of either interior or complementary area but were not found to give rise to recognition of <u>conservation</u>

of interior before complementary area, as would have been expected. Piaget had found children who recognised and gave reasons for conservation of interior but not complementary area as well as children who recognised equality of interior area but gave no reasons for conservation and did not recognise equality or conservation of complementary area. The present investigation did not find any children at the former level but only at the latter; no separation of understanding of conservation of interior area from understanding of complementary area was evidenced. (The different findings may be the result of differences in the criteria for conservation as well as in the actual situations presented).

The recognition of equality of area for slight transformations only, could be explained by the particulars of the situation; perceptual judgment only was involved. The possibility of perceptual judgment of equality in certain area situations may explain the results in this investigation without necessitating a theory about understanding conservation of interior as opposed to complementary area.

The findings in the present investigation differed from Piaget's in another way. In the houses on fields area situation children found it harder (not easier as Piaget had found) to recognise conservation than in the plots on fields area situations. Quite a few children recognised and gave reasons for conservation in every pre-test situation except the houses on fields area situation. Piaget has not found this to be the case, and in explanation of the fact that he found conservation of area in the houses on fields situation to be easier than conservation of complementary area in the plots on fields situation, he wrote that in the houses situation "there was only one problem of conservation since the child was told right from the start that one of the areas was invariant and the other was complementary to it" whereas the plots situation is harder "for two reasons: it involves two separate problems of conservation, each dealing with separate areas, and the child must find out for himself that these complement one another" (Piaget, Inhelder, & Szeminska (1960) p.290). Piaget's explanation does not seem the necessary one; it is not evident that the children must consider the complementary relation before they can conserve field area in the plots on the fields situation. Moreover, Piaget's order of difficulty was not found in the present investigation; both Goldschmid (1967) and the present writer have found the reverse order.

In the case of distance, when the conservation problem was presented in suc a way that the children clearly understood the distance in question, i.e. when the experimenter specifically named and pointed the distance between the objects, all the children recognised the continuing equality. Perceptual judgments may be all that were necessary, for example, one child, a nonconserver in all the other attribute situations, explained "I see 'em there and there". While some children explained their judgments as Piaget's conservers did (Piaget, Inhelder & Szeminska (1960)) by mentioning the fact that "they haven't moved", no explanations given in the distance situations included the type of identity, reversibility and compensation reasons for conservation appropriate in all the other attribute situations. The distance situation is basically different from the other attribute situations and the reasons required are different; thus, distance fits less clearly into a sequence with the other attributes.

When Piaget found nonconservers of distance, he found that "the vast majority think the interval is less", "nearly all believe that the distance ...... is reduced by an amount equal to the width of the screen". (Piaget, Inhelder & Szeminska (1960) pp. 72 & 78). This finding suggests that it may be the pointing of the distance through the divider in the present investigation which helps the children most. However, the naming and pointing which counters faulty consideration of the distance between object and divider, as well as the pointing of the distance through the divider which counters faulty consideration of a detour over or around it in addition to emphasising the inclusion of the width of the screen, may be important. Children's comments such as "It's the same far - It's just half to that" (divider) indicate the importance of their understanding the distance in question is object to object not to divider. Likewise, Piaget did find a few children who believed the distance become greater, and the present writer, in questioning children not included in this investigation, has found that when demonstration of the distance going through the divider is omitted children sometimes say "It's farer going over" or "it's farther 'cause that (divider) stops you". Thus, the particular presentation of the distance problem may serve to clarify several points for the child.

Returning to the present investigation, no children were found who considered "only a part of the whole with which they began" as Piaget had found "stage I" children to do. Piaget suggested "that the introduction of the screen puts an end to any distance relation between" the objects for the "stage I" children; "the two intervals separated by the screen cannot be brought together in a single whole" by these nonconservers (Piaget, Inhelder & Szeminska (1960) p.72). No such children were found in this investigation. No "stage IIA" nonconservers were found either; such children Piaget had found to deny the continuing equality of distance when a screen was introduced though, unlike the "stage I" children, they considered the "overall distance . . . whatever the intervening objects". Strictly distance conservation problems and not distance symmetry problems were presented in the present investigation and so there could be no identification of Piaget's "stage II B" children as opposed to the "stage III" conservers.

All the children studied in the present investigation recognised the equality in all the distance situations presented. Piaget theorised that children who recognised and gave reasons for the continuing equality in the distance situations have a concept of invariant linear distances which "implies the recognition of space as a container, no longer as split into contents or filled space, and absence of content, or empty space". "Distances" Piaget wrote "are symmetrical intervals which are extracted from groupings of asymmetrical relations of order of position and change of position (change of order or serial position). This step becomes possible when these operational groupings have been accomplished at a qualitative level" (Piaget, Inhelder, & Szeminska (1960) p.85). In the present investigation there was no evidence that such understanding was involved when children recognised the continuing equality. That all the children recognised the equality in this investigation might be explained simply by the fact that they considered, correctly, the distance in question perhaps making perceptual judgments only.

In the case of length, situational differences again were important. Children recognised equality of length more easily in some situations than in others; the order of increasing difficulty was: staggered sticks before Mueller Lyer sticks before paper strips equality. The difficulty in any particular situation was not due to misunderstanding of the question; pointing the length under consideration, e.g. up and down the paper strips, ensured that the children understood the length in question and that it was not always a straight path between the extremities.

Perceptual judgments of equality were possible in the staggered sticks and even in the Mueller Lyer sticks transformations, for example, some children said "they don't look a different length" and some insisted "they look the same" and not just that they knew they were the same length. The Mueller Lyer transformation did not entirely eliminate the possibility of correct judgments for purely perceptual reasons. This may have been because wooden sticks were used in the black cardboard arrowheads thereby diminishing the effectiveness of the illusion.

The Mueller Lyer illustion was used in the present investigation in order to study the influence of starting and stopping points on children's judgments in the length situations, as well as in an attempt to counter purely perceptual judgments of equality. In the Mueller Lyer transformation the extremities of the sticks coincided after as well as before the transformation, whereas in the staggered sticks transformation the extremities did not coincide afterwards. Whether nonconservers based their judgments on starting and stopping points and/or on the general perceptual effect was not entirely clear, but since children were found who were nonconservers in the Mueller Lyer sticks as well as staggered sticks transformation, more than just starting and stopping points were shown to influence nonconservation judgments.

In the present investigation, no sharp distinction was made between situations that tap pre-operational ways of thinking (e.g. the conservation situations) and those that tap a perceptual illusion (e.g. the Mueller Lyer situations), though it has been suggested that Piaget might regard the processes involved as different in kind and in the course of development (see Elkind & Flavell (1969) pp. 446-447). No such absolute distinction between perception and thought was considered appropriate and Piaget himself (Piaget, Inhelder & Szeminska (1960)) has introduced perceptual illusions in studying conservation of length (e.g. sticks "arranged in a T" . . . . " a familiar perceptual illusion").

In the main, the findings in the length situations of the present investigation supported Piaget's. Length conservation was seen to arise after number conservation, and at approximately the same time as substance conservation, and before weight and volume conservation; the place of length in the attribute sequence was as Piaget had found. Likewise, the length conservation problem was found to be "more complicated when it concerns the overall length of a series which may be cut and subdivided in a variety of ways" (Piaget, Inhelder, & Szeminska (1960) p.115); as Piaget had noted, situational differences were important and conservation was harder to recognise in the paper strips length situation. More than "end points", or starting and stopping points, were found to influence nonconservation judgments; it appeared, as Piaget had found in relation to the strips of paper length problems, that "a variety of factors tend to bring about nonconservation of length" (Piaget, Inhelder, & Szeminska (1960) p.108). Lastly, although the present investigation did not reveal all the "intermediate responses" or "transitory steps" in the development of length conservation that Piaget had found (Piaget, Inhelder & Szeminska (1960) pp.100-101), a further detailed investigation of length conservation by itself might well disclose levels of understanding in ESN children similar to those that Piaget described.

In the case of volume, which had been studied in Investigations Two and Three, situational differences were again shown to be important. Conservation of volume appeared to be more easily recognised in some situations than in others but there was no evidence of a necessary interior-before-displacement volume conservation sequence such as Piaget had described; the findings in the present investigation supported those in the writer's prior investigations which showed that conservation is not necessarily recognised for interior before displacement volume. Different displacement volume situations gave rise to differences in recognition of conservation. The difference in difficulty between the two displacement volume situations may be a result of the fact that in one situation the objects are in water and the question of displacement emphasised whereas in the other situation transformations are actually carried out, comparison objects are present, and the question of conservation emphasised.

More than purely perceptual judgments were made when the continuing equality was recognised in some but not other volume situations; reasons for conservation were given though conservation was not recognised in all the volume situations.

The same was true in the case of number and in the case of substance; situational differences were important and some children recognised and gave reasons for conservation in one but not both material situations for each of these two attributes. No further transformational differences were found for number or substance conservation, for example, bunching or spreading the flowers near or far from the jars did not give rise to differences in the children's judgments though Piaget (1952) had discovered such differences.

No situational differences were found in the case of weight. This was perhaps because the transformations of the different materials were more similar for the weight conservation situations than for any of the other attribute situations.

Thus, although the findings of the present investigation in some attribute situations were very similar to Piaget's those in other attribute situations were less so. Situational differences were found to be of great importance. In area, distance, and length situations children were found who made perceptual judgments of equality for certain transformations and in area, volume, number and substance situations children were found who recognised and gave reasons for conservation in some but not other material situations. Differences in the extent of the transformations gave rise to differences in perceptual recognition of equality and differences in the material situations gave rise to differences in conceptual recognition of conservation. Such situational differences may explain the differences found in children's judgments in area and volume situations without introducing distinctions between understanding of interior and complementary area or interior and displacement volume. However, situational differences are not the whole explanation of the differences in the children's judgments and differences in judgments within the different attribute situations can not be explained in exactly the same way; purely perceptual judgments of equality were sometimes made in area situations but not in volume situations so there is no exact parallel between interior/complementary area and interior/displacement volume findings although both can be explained in terms of situational differences and in both cases conservation was sometimes recognised for some but not other materials.

Finally, it was again clear from testing the same children in different situations that understanding of conservation did not develop in an all-or-none manner. Conservation was sometimes recognised for one but not another attribute or for one but not another material or for one but not another transformation.

The third question answered in the present investigation was whether conservation in a general sense and conservation of area can be taught to educationally subnormal children. Both were found to be possible; a generalised understanding of conservation was developed equally effectively using the two different teaching schemes. The brief but varied explanations and experiences given in the teaching schemes were effective in developing understanding of conservation in thirty of the thirty-four children given instruction.

No single aspect of the teaching was isolated as being the most important or essential, but certain aspects were observed to be particularly helpful or convincing for the children. The use of an external criterion in demonstrating conservation was one such effective method. An external measure was introduced where simple and appropriate to provide clear evidence for conservation. Counting in the number situation countered purely perceptual misjudgments, marking off equality of lengths while the sticks were in transformation provided a simple measure of conservation, counting rectangles on a grid covering areas of different shapes and marking off levels of displacement likewise provided relatively simple criteria which did not require mathematical multiplication. The effective use of a measure, or external criterion, in the teaching did not require children's prior understanding of conservation in the attribute situation nor of units of measurement or unit iteration; all that was required was comparison with a standard or identical actions to reveal the equality. Such use of an external criterion, a very simple form of measurement, was appropriate for teaching nonconservers. It provided evidence for conservation at a perceptual level and it clarified the distinction between appearance and reality for the children. Educationally subnormal children who recognised conservation 'naturally', often, to prove their conservation judgments, counted spontaneously or suggested using a ruler or scale and, though they did not suggest using a grid or measuring displacement, they easily recognised their import (e.g. saw the relation to the rise of the water in a swimming bath when children get in etc.). These children found an external criterion very helpful in the conservation situations and so, it was found, did the nonconservers when given instruction.

The effective use of an external criterion in developing understanding of conservation does not run counter to Piaget's emphasis throughout The Child's Conception of Geometry on the fact that conservation is prerequisite for measurement (e.g. Piaget, Inhelder & Szeminska (1960) pp. 64-66, 85, 90, 122-3, 128, 296-301, 384-5, 397). By measurement, Piaget states, "we mean unit iteration" (Ibid.p.397); no such unit interation was required in using an external criterion in the present investigation. Whether "conservation antecedes measurement or is the outcome of measurement" (Ibid. p.68) is not a problem in the present investigation. The use of an external criterion was found, in this investigation as in Investigations One, Two and Three, to help develop recognition of conservation as part of a whole case for conservation presented to the children; understanding of conservation may have been partly developed before any measure was introduced. Likewise, it may be that any conservation involved in the measuring was simpler and understood before the conservation problems which involved perceptual contradiction; conservation does not develop in an all or none manner so sufficient understanding for a simple form of measuring may have developed before conservation in the particular situation was recognised. Thus the use of an external criterion to develop conservation is logically appropriate as well as effective in practice.

One other particularly effective aspect of the teaching appeared to be the explanation that nothing had been added or taken away. This 'quantitative' identity type reason was the one most frequently used by the children taught in the present investigation; they found it both convincing and easy to apply in new situations. But it was not the reason most frequently used by children taught in the prior investigations; in Investigations One, Two and Three the 'qualitative' form of identity reason, identity of material, was most often mentioned to justify conservation judgments.

What seemed clear in the present investigation, as in the prior investigations, was that there was no single effective and essential ingredient of the teaching schemes; what appeared to be most important to the effectiveness of both teaching schemes was the variety of explanations and methods. Different children have different needs and all will develop a fuller understanding through being given varied rather than restricted explanations and experiences. The purpose of the teaching schemes was to develop a generalised understanding of conservation in a range of situations and not to define minimal elements in the development of conservation; the aim was to help the children to attend to the relevant factors, the cues for constancy, in different conservation situations and to resist being perceptually misled.

The varied explanations and experiences given in both teaching schemes developed recognition of a general principle of conservation, recognition of the reality underlying appearances, in increasingly difficult situations. The understanding of conservation developed was both generalised and durable. The children recognised and gave clear reasons for conservation in situations where they had not before, in new material situations, and in inequality situations, and this understanding of conservation was lasting, as evidenced when the children were tested two months after the teaching. The explanations given on the post-tests by the 'taught' conservers were as full as, or fuller than, those given on the pre-test by the 'natural' conservers. The only difference was in the frequency of identity and reversibility reasons; 'taught' conservers gave identity more than reversibility reasons, 'natural' conservers did the reverse. No attempt was made to test the children's resistance to countersuggestion; all of the 'taught' conservers gave clear reasons for their judgments and Smedslund (1966) has found 97 - 100% of children who give reasons for conservation resist countersuggestion. It seemed quite unnecessary, as well as unfair, for the experimenter to attempt to 'extinguish' conservation responses in these educationally subnormal children.

Whether the teaching helped these children to apply a prior partial understanding of conservation to new situations or developed a new understanding is not a question asked in this investigation; in terms of their behaviour, the children can be said to have learned to recognise and give reasons for conservation where they did not do so before. That the understanding of conservation developed by the teaching may be the result of activation of an existing structure rather than creation of a new structure does not lessen its practical importance. Moreover, as long as conservation of an attribute is not regarded as a discrete concept, i.e. as long as the continuity of development of understanding is recognised, the problem whether an existing structure is activated by the teaching rather than a new one created need not arise. What can be said is that children in the present experiment were helped to generate an appreciation of invariance for a range of attribute situations, and that both the T1 and T2 teaching schemes were equally effective in developing such understanding, and that this understanding did not develop spontaneously in the control group children over the two month period.

The last question studied in the present investigation was that of the influence of degree of initial understanding of conservation. Children who exhibited no initial understanding of conservation, i.e. who failed even to recognise conservation in the number situations of the pre-test, did not learn from the teaching given; but children who had different degrees of initial understanding of conservation beyond conservation of number learned and learned equally well. As long as children recognised conservation of number, no further degree of initial understanding of conservation appeared to affect their response to the teaching.

Conservation of number thus appeared to be necessary before children could learn from the brief teaching schemes used in this experiment, but this needs further investigation. It might be more accurate to say that children need to have reached a level of understanding indicated by recognition of conservation in the number situations of the pre-test in order to benefit from the teaching given. It may not be conservation of number that is essential but rather the understandings prerequisite for this. The teaching given to both the T1 and T2 groups built upon prior understanding and assumed certain basic awarenesses and abilities. For example, it necessitated, among other things, an awareness of the effect of addition or subtraction of material. No attempt was made to develop such preliminary awareness although understanding of the argument that because nothing had been added or taken away the quantity must be the same depended upon this awareness.

The nonconservers of number studied in the present experiment were able to make appropriate comparisons, discriminate similarities and differences, correctly count out objects, and understand the terms of the conservation problems but they did not appreciate the significance of the argument that since nothing had been added or taken away the quantity must be the same. Whether they failed to understand the effect of addition/subtraction and its relation to sameness or whether they failed to understand the if........then reasoning in the argument for conservation or whether it was the combination that was too difficult for them was not clear. In any case, probably more than just failure to understand the effect of addition/subtraction in relation to sameness and/or failure to understand the logic of the argument led to their failure to learn from the teaching schemes; they had also been given other explanations and experiences which had not developed understanding of conservation.

These total nonconservers did not develop understanding of conservation when the brief teaching schemes of this experiment were used, but such children might have learned from different fuller teaching. Even nonconservers of number might have learned if the teaching had been more like that given in Investigations One and Two where the teaching concentrated in much greater detail on conservation of one attribute, weight or volume.

When in Investigation Three the teaching was systematically reduced, children with less initial understanding of conservation were found to learn less well and sometimes not to develop understanding of conservation at all. In other words, in Investigation Three as in the present investigation, the effectiveness of the teaching appeared to be influenced by an interaction between degree of initial understanding and fullness of the teaching scheme. No close comparison, however, between the results of the two experiments is possible because conservation in the number situations was not tested in the prior experiment.

In the present investigation it was not clear exactly why the four total nonconservers failed to develop conservation. The brief teaching schemes were effective in developing understanding of conservation in all but these four children. Further investigation might reveal why nonconservers of number did not develop understanding of conservation from the teaching given and whether using different teaching schemes such understanding can be developed in educationally subnormal children at this level of understanding. Detailed exploration of total nonconservers' understanding and difficulties in understanding might reveal more clearly what their level of understanding actually is, i.e. what they do as well as do not understand, and on the basis of their responses more appropriate teaching might be given. In Investigation Five, concentration on understanding in simple number situations was found to help three out of the four total nonconservers to develop understanding of conservation.

Finally considering the investigation as a whole, it can be said to have answered the broad questions of sequence in the natural development of conservation and influence of situational differences on recognition of conservation, as well as questions on the possibility of developing conservation in a general sense and conservation of area so that it is generalised. Further detailed investigation of children's understanding of conservation in number and perhaps one or two other attribute situations might answer questions not fully answered in this investigation. The role of initial understanding needed to be further clarified; whether educationally subnormal children who do not recognise conservation even in number situations can be successfully taught conservation remained to be answered and was answered in Investigation Five.

IV APPENDIX

Pre-testing Procedure for Investigation Four.

1a. Look at these two glasses with beads in them (two identical 100ml beakers each containing six beads of 2cm diameter)

Is there the same number of beads in each glass?

If you have this glass and I have that glass (pointing) have we as many beads as each other?

(After recognition of equality or making equal)

If I do this to mine (pour one beaker of beads into taller, thinner container)

Is there still the same number of beads?

Do we still have as many beads as each other?

Why do you think so?

(Repeat procedure using two sets of twelve similar beads but substituting wide for tall thin container)

1b. Look at these jars each with a flower in it (ten identical jars with ten identical plastic flowers)

Is there the same number of flowers as jars?

Are there as many flowers as jars?

(After recognition of equality or making equal)

If I do this (remove flowers from jars and put them in a bunch near the jars)

Is there still the same number of flowers as jars?

Are there still as many flowers as jars?

Why do you think so?

(Put flowers back into jars and repeat questions removing flowers and spreading them out far from the jars)

1c. Look at these jars and flowers (ten identical jars, eight containing one flower each, two empty)

Is there the same number of flowers as jars?

Are there as many flowers as jars?

2a. Here are two glasses of orange (two identical 100ml beakers $\frac{1}{4}$ full of orange squash)

If you have this glass and I have that glass (pointing) have we equal amounts to drink, fair shares?

Is there the same amount of orange in each glass?
(After recognition of equality or making equal)
If I do this to mine (pour one drink into low container)
Do we still have equal amounts to drink, fair shares?
Is there still the same amount of orange?
Why do you think so?
(Repour drinks into original beakers and repeat questions pouring one drink into four 25ml beakers)

2b. Here are two balls of plasticine (two identical balls approximately 4cm in diameter)
If you have this ball and I have that ball (pointing) have we equal amounts of plasticine, fair shares?
Is there the same amount of plasticine in each ball?
(After recognition of equality or making equal)
If I do this to mine (roll one ball into sausage approximately 9cm long)
Do we still have equal amounts of plasticine, fair shares?
Is there still the same amount of plasticine?
Why do you think so?
(Remake two balls and repeat questions cutting one plasticine ball into seven pieces)

2c. Here are two glasses of orange (one 100ml beaker $\frac{1}{4}$ full, other 100ml beaker $\frac{3}{4}$ full)
Do we have equal amounts to drink, fair shares?
Is there the same amount of orange in each glass?

3a. Look at these two sticks (two identical 10cm sticks laid parallel with ends coinciding, approximately 2.5cm apart)
Are the sticks the same length as each other?
Is it as long from here to here (pointing) as from here to here (pointing)?
(After recognition of equality or making equal)
If I do this (move both sticks so that top stick is 7cm farther to the right but sticks are still parallel)
Are the sticks still the same length as each other?

Is it still as long from here to here (pointing) as
from here to here (pointing)?
Why do you think so?
(Substitute two identical 20cm sticks and repeat
questions moving the sticks into Mueller Lyer arrowheads)

3b. Look at these strips of paper (two identical 30cm x 1cm
white paper strips)
Are the strips the same length as each other?
Is it as long from here to here (pointing) as from here
to here (pointing)?
(After recognition of equality or making equal)
If I do this (cut one strip in half and form into
90° angle)
Are the strips here to here and here to here (tracing
over both 30cm lengths) still the same length as each
other?
Is it still as long from here to here (pointing) as
from here to here (pointing)?
Why do you think so?
(Return to original situation with two fresh uncut
strips and repeat questions cutting one strip into
four unequal pieces and forming them into a zig-zag)

3c. Look at these two sticks (two unequal sticks, one 20cm,
the other 10cm, laid parallel approximately 1" apart)
Are the sticks the same length as each other?
Is it as long from here to here (pointing) as from
here to here (pointing)?

4a. Here are two trees (two identical plastic trees
approximately 5cm high placed 50cm apart)
Are the trees near together or far apart?
Is it near or far going from here to here (pointing)?
(After recognition of nearness or farness)
If I do this (put 7.5cm high cardboard screen with
window half way between the two trees)
Are the trees still as far apart (or near together)
(pointing)?
Is it still as far (or near) going from here to here
(pointing)?

Why do you think so?

(Remove screen and repeat questions putting 7.5cm high, 2.5cm thick wooden screen half way between the two trees)

4b. Here are two trees (two identical plastic trees , approximately 5cm high placed 5cm apart)

Are the trees near together or far apart?

Is it near or far going from here to here (pointing)?

If I do this (move trees further apart or nearer together)

Are the trees still as near together (or far apart)?

Is it still as near (or far) going from here to here (pointing)?

5a. Look at these two green fields with houses on them (two identical sheets of green perspex approximately 20cm x 30cm each with two identical houses approximately 2 x 1 x 2cm, similarly positioned)

Is there as much space for grass here as here (pointing to two fields)?

Is there the same amount of green space here as here (pointing as above)?

(After recognition of equality or making equal)

If I do this (move one pair of houses farther apart)

Is there still as much space for grass here as here?

Is there still the same amount of green space?

Why do you think so?

(Repeat procedure using four then twelve then twenty houses in each field)

5b. Look at these two green fields with potato plots in them (two identical sheets of green perspex approximately 20cm x 30cm, each with a 12cm square of brown cardboard on it, one piece pre-cut into 2 rectangles)

Is there as much space for potatoes here as here, the same amount of brown space (pointing to two plots)?

Is there as much space for grass here as here, the same amount of green space (pointing to two fields)?

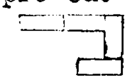
(After recognition of equality or making equal)

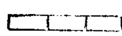
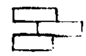
If I do this (re-arrange cut square to form elongated rectangle)

Is there still as much space for potatoes here as here, the same amount of brown space ?

Is there still as much space for grass here as here, the same amount of green space?

Why do you think so?

(Repeat procedure substituting 12cm square pre-cut into 4 rectangles and then re-arranged to form  shape)

(Repeat above procedure but substituting one green perspex field pre-cut into 3 rectangles to be transformed in the following ways:  and  and substituting two identical and uncut 9cm square pieces of brown cardboard)

5c. Look at these two green fields with houses on them (two identical sheets of green perspex approximately 20cm x 30cm each but with two houses on one and twenty houses on the other)

Is there as much space for grass here as here (pointing to two fields)?

Is there the same amount of green space here as here (pointing as above)?

6a. Would you hold these two balls of plasticine (two identical balls approximately 4cm in diameter)

Do they weigh the same as each other?

Are they equal in weight?

(After recognition of equality or making equal)

If I do this to this one (flatten one ball into pancake approximately 6.5cm in diameter)

Does it still weigh the same?

Are they still equal in weight?

Why do you think so?

(Remake two balls and repeat questions cutting one plasticine ball into ten pieces)

6b. Would you hold these two pieces of cotton-wool (two identical pieces)

Do they weigh the same as each other?

Are they equal in weight?

(After recognition of equality or making equal)

If I do this (roll out one piece)
Does it still weigh the same?
Are the pieces still equal in weight?
Why do you think so?
(Reform two identical pieces and repeat questions compressing one piece)

6c. Would you hold these two balls of plasticine (one two times as large and heavy as the other)
Do they weigh the same as each other?
Are they equal in weight?

7a. Look at these two buildings (two 6 x 3 x 2 1cm wooden-unit-cube buildings)
Have they the same room in them as each other?
If you lived in this one and I lived in that one, would we have equally much room inside our building to live in?
(After recognition of equality or making equal)
If I do this to mine (make 12 x 3 x 1 building out of one 6 x 3 x 2 building)
Does my building still have the same room in it?
Do our buildings still have equally much room inside them?
Why do you think so?
(Remake two buildings 6 x 3 x 2 and repeat questions making one building 36 x 1 x 1)

7b. Look at these metal blocks (4 x 3 x 3 1cm metal unit cubes) and dish of water
I'll mark where the water comes to
Watch what happens to the water level (pointing) when I put the blocks in the water (demonstrating)
If these blocks were spread along the bottom of the dish
Would the water level still be the same as now, come to the same place?
Would these blocks still take up the same amount of room in the water?
Why do you think so?
(Repeat for if the blocks were part in each corner of the dish)

7c. Look at these two lots of metal blocks (two 4 x 3 x 3 1cm metal-unit-cube constructions)
Would they make the water level rise the same, rise equally far?
Would they take up the same amount of room in the water?
(After recognition of equality or making equal)
If I do this (make one lot of blocks 6 x 6 x 1)
Would they still make the water level rise the same, rise equally far?
Would they still take up the same amount of room in the water?
Why do you think so?
(Remake two lots 4 x 3 x 3 and repeat questions separating one lot into four overlapping pieces)

7d. Look at these two buildings (one 6 x 3 x 2 and one 6 x 3 x 1 1cm wooden-unit-cube buildings)
Have they the same room in them as each other?
If you lived in this one and I lived in that one, would we have equally much room inside our buildings to live in?

Post-testing Procedure for Investigation Four.

1a. Repeat pre-test 1b bunching flowers only

1b. Repeat pre-test 1b but substituting two rows of 12 1.8cm wooden cubes of assorted colours and spreading one row only

1c. Repeat pre-test 1a using 12 beads and the wide container transformation only

1d. Repeat pre-test 1a but substituting unequally filled beakers, one with 6 the other with 12 beads, and using the tall thin container transformation only.

2a. Repeat pre-test 2a pouring orange drink into low container only

2b. Repeat pre-test 2a but substituting sand and pouring it into a large flask only

2c. Repeat pre-test 2b rolling ball into sausage only

2d. Repeat pre-test 2b but substituting unequal amounts of plasticine, one ball twice as large as the other, and cutting the larger only into 7 pieces

3a. Repeat pre-test 3a staggering 10cm sticks only

3b. Repeat pre-test 3a but substituting wires 18cm long and transforming one into an arc only

3c. Repeat pre-test 3b cutting one strip to form the zigzag only

3d. Repeat pre-test 3b but substituting unequally long paper strips, one twice as long as the other, and cutting the longer only to form 90° angle

4a. Repeat pre-test 5b using the four piece potato plot transformation only

4b. Repeat pre-test 5b but substituting two red felt-coated cardboard grounds 38 x 31cm, one pre-cut to be transformed into a diamond shape and each with one blue felt 8cm diameter circle on it, and presenting the transformation vertically only

4c. Repeat pre-test 5a using 20 houses only

4d. Repeat pre-test 5a but substituting an unequal number of houses on the two fields, 12 houses on one and 20 houses on the other, and moving the 12 houses only farther apart

5a. Repeat pre-test 6a flattening ball into pancake only

5b. Repeat pre-test 6a but substituting meccano lattices and collapsing one only

5c. Repeat pre-test 6b rolling out one piece of cotton only

5d. Repeat pre-test 6a but substituting unequal pieces of plasticine, one piece six times as large as the other, and cutting the larger only into 10 pieces

6a. Repeat pre-test 7b for spread along bottom of dish only

6b. Repeat pre-test 7b but substituting equal volume differentially weighted (and recognised as such) balls of plasticine for part in each corner of dish only

6c. Repeat pre-test 7c making 6 x 6 x 1 transformation only

6d. Repeat pre-test 7c but substituting equal volume differentially weighted (again recognised as such) balls of plasticine and transforming one into an overlapping zigzag only

6e. Repeat pre-test 7a making 12 x 3 x 1 transformation only

8i. Repeat pre-test 7a but substituting unequal wooden-unit-cube buildings, one 6 x 3 x 2cm the other 6 x 2 x 2cm, and making the smaller 12 x 2 x 1 only.

Comparison of Findings on the Sequence Substance-Weight-Volume

	Invest. 2	Invest. 3	Invest. 4	Total
Crs subs, Ncrs wt & vol	7(8)	2(4)	20(29)	29(41)
Crs subs & wt, Ncrs vol	11(11)	10(18)	31(31)	52(60)
Exceptions	1(3)	0(2)	0(1)	1(6)

Bracketed numbers are those found when children who evidenced conservation in some but not other situations for an attribute are included.

Unbracketed numbers include only children who recognised or failed to recognise conservation in all the situations for any one attribute and not those who evidenced conservation in some but not other situations for an attribute.

CHAPTER 6

THE DEVELOPMENT OF UNDERSTANDING OF NUMBER CONSERVATION

I INTRODUCTION

The aim of Investigation Five was to explore, and attempt to develop, educationally subnormal children's understanding of number and conservation. Children who had exhibited no understanding of conservation in number, substance, length, area, weight and volume situations and who had not developed any such understanding after being given teaching effective for thirty other children were here more closely studied and given fuller instruction. This was done in order to find out whether educationally subnormal children who do not recognise conservation even in number situations can be successfully taught conservation and to obtain a clearer picture of how such understanding may develop.

In Investigation Four all but four of the thirty-four children given brief teaching had developed understanding of conservation. All except these four children had, when pre-tested, recognised conservation in number situations though not in all other attribute situations. It appeared possible, therefore, that initial understanding of number conservation was important to the effectiveness of the teaching. The present investigation was designed to find out whether children without the degree of understanding indicated by conservation of number can be given a generalised understanding of conservation. Where brief teaching of conservation alone was given in the prior investigation, very full teaching of more than just conservation was given in the present investigation. Careful record was kept of each child's responses in the varied problem situations so that the development of understanding in individual children could be studied in greater detail.

II PROCEDURE AND RESULTS

Six children, Gail aged 12. 3 IQ 56, Robert 11.4 IQ 50, John 11.0 IQ 51, Paulette 13.8 IQ 67, Kevin 13.10 IQ 63 and Paul 13.11 IQ 79, were tested for conservation of number. All were found to be nonconservers still. Four of the children, Gail, Robert, Paulette and Kevin, not successfully taught in the prior investigation and matched for CA and IQ - Gail and Robert (control John) and Paulette and Kevin (control Paul), were given fuller teaching. All six children were then tested for conservation of number, substance, and weight one week and again two weeks after the four were taught.

The materials used were: Pre-test-1.8cm diameter beads, 100ml beakers, glass tube 10cm long 2.5cm **diameter**, clear plastic box 14 x 8 x 2 cms, 2-D eggs and eggcups, Teaching - 1.8cm diameter beads, 50ml beakers, glass tube 10cm long 2.5cm diameter, dot distribution cards, sweets, pennies, 2-D eggs and eggcups, counters, draughts, 1.8cm cubes, classification cards, 100ml beakers, 25ml beakers, 1cm cubes, glass tube 16cm long 2.5cm diameter, glass jar 7cm high 6cm diameter, clear plastic box 14x8x5cms, rubber bands, water, opaque box 11x7x5cm, translucent box of similar measurements, petri dish, Cuisenaire rods, L shaped frame, cardboard dolls and sticks, 'Lego' cubes, Post-test - 1.8cm diameter beads, 100ml beakers, glass tube 10cm long 2.5cm diameter, clear plastic box 14x8x2cms, nuts, 50ml beakers, petri dishes, glass tube 6cm long 1.5cm diameter, 2-D eggs and eggcups, toy houses, water, plasticine, knife, rice, plastic bags.

Pre-and post-test situations and questions were carefully presented so as not to bias children's responses; the procedure was standard but flexible. Care was taken that children understood questions as they were intended. Before being questioned on conservation in any situation children were asked to create equality for the attribute under consideration. The conservation question was then asked in four different ways: "What about now" with no mention of sameness or difference, then a question including the word "same" separated from a question including the word "different" as a check for consistency, and finally a rewording of the sameness question for clarification. Explanation of reasons for judgments made were sought and more than one transformation was made in every attribute situation. (Detailed descriptions of the test situations and questions are given in the chapter appendix).

All the children were seen alone in a quiet room of the school. The experimenter made all transformations in full view of the children who sat beside her. After children made judgments in the test situations the experimenter made only non-committal remarks and encouraged them to explain why they thought what they did. These explanations were taken as evidence of conservation or nonconservation and the children's performance was recorded.

The teaching method used to develop the children's understanding of conservation was both extensive and intensive in that a wide variety of problem situations, experiences, materials and explanations were presented within a single teaching session of approximately 90 minutes. The aim was to help children who had not responded to prior teaching of conservation by presenting this time a range of problems which might be expected to be basic to an understanding of conservation. Conservation was treated as a complex of sub-problems and the teaching concentrated on these various sub-stages as individual problems in their own right. The teaching was designed to direct the children's attention to what was central to conservation and to prevent their being distracted by irrelevant aspects of the situations. The variety of experiences and explanations was assembled to enable the children to structure their own learning; the children were expected to have different sources of difficulty and to develop appreciation of conservation in different ways.

(i) Pre-testing.

The pre-test included number conservation problems only, because the prior investigation had shown without exception that number conservation is recognised before conservation of other attributes. Children who failed to recognise conservation in number situations could be expected to do the same in substance and weight and other attribute situations.

Piaget's beads-into-different-containers and egg-and-eggcup-provoked-correspondence conservation situations were presented (Piaget (1952) Chapts. 2 and 3). Eight and then 12 beads were transferred, the smaller number into a tall thin tube and then the larger number into a low wide dish; then 7 and 11 eggs were bunched near to and spread far from their eggcups. Questions of "number" specifically and not "amount" were asked.

Each child was seen alone for approximately 5 minutes.

All six children tested were found to be nonconservers of number still - 7 months after they were originally tested. The criterion for nonconservation of number was failure to recognise equality in number in every pre-test situation after material was transformed in appearance while also giving a clear indication which portion was considered greater or less and why.

(ii) Teaching.

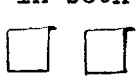
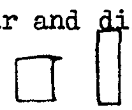
The four children, two girls and two boys, for whom the brief teaching of the prior investigation had been ineffective were given fuller different teaching, teaching which was designed to develop a basic general understanding of number as well as, and as a basis for, understanding of conservation. Detailed consideration of various simple number problems and not just conservation itself was included in the teaching which explored and then attempted to develop each child's understanding. Each child was given a chance to solve comparison, correspondence, creation of equality/inequality, addition/subtraction, conservation, and seriation problems before being instructed in those problem situations and a close record was kept of the development of his understanding, of how each child reacted to every step of the teaching. The teaching built upon what the child did understand and was adapted to his individual needs though it was kept within standard limits. (See the chapter appendix). Each child was seen alone and participated willingly and attentively for 80 to 90 minutes in a single teaching session. In each case the variety of the materials and problems held the child's interest. Natural rest periods were given.

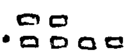
The standard teaching procedure included 6 basic types of problems. First, comparison problems were presented. These involved similar and different numbers of beads in similar and different shaped containers, dot distributions with similar and different numbers and extremities, and similar numbers of blocks in different combinations. Each child was asked if there were the "same number, as many", or a "different number" and "which (portion) was more, which less", how he could "find out", whether "counting would help", etc. The distinction between "more in number" and "longer, higher", etc. was made clear. Second, one to one correspondence problems were presented. Questions were asked about the number of sweets and pennies in an exchange situation. After 'buying' sweets one at a time for a penny each and with the sweets spread out and the pennies in a pile, the child was asked if there were the "same number, as many" or if there were "more pennies or more sweets" and why he thought what he did. The procedure was repeated and the situation explained. Then the child was asked to "put out the same number, just as many as there are here" eggs as eggcups (provoked correspondence), counters in a row and draughts in a pile (unprovoked horizontal and vertical correspondence). Next the child counted to find out how many blocks were presented and to select the required number (cardinal number to object correspondence). And finally, the child classified pictured shapes by number, that is, he grouped together cards with the same number of objects drawn on them. Third, problems of creating equality and inequality were presented. Each child was asked to "put the same number, just as many in each (portion), make fair shares" in similar and then in different shaped containers using a pile of unit cubes. Then he was asked to make one share greater than the other by specified numbers, first using containers and a pile of unit cubes, and then using no containers and working from unequally distributed unit cubes. Fourth, addition/subtraction problems were presented. One counter was subtracted from one of two recognised-as-equal rows and then one was added to one of two other recognised-as-equal rows. The child was asked after each subtraction or addition if there were the "same number, as many" or a "different number" and "which (was) more and which less" and why he thought what he did. The fact that taking some away makes the number less and adding some makes it more was emphasised as a basis for the recognition that unless some are added or taken away the number remains the same. The procedure was repeated with draughts in two piles. Fifth, conservation problems were presented. Identity and then equivalence situations were used; that is, one portion only was present and transformed for the first conservation questions and then one of two equal portions was transformed and conservation questions asked. At first no comparison portion was present to distract the child's attention from the identity of the materials transformed. A single container of beads was simply moved as a whole from vertical to horizontal and vice versa, then beads were transferred from one container to another, next a single row of blocks was bunched and spread and then covered, then a rubber band was stretched and finally water was poured from one container to another. Conservation in equivalence situations was then introduced. Eggs and eggcups matched one to one were bunched and spread, one of two recognised-as-equal piles of draughts was rearranged, one of two recognised-as-equal-or-unequal portions of beads were transferred to different shaped containers, one of a pair of rubber bands was stretched and finally, one of two equal portions of water was poured into a different shaped container. After transformations each child was asked "what about now", is there the "same number, as many" or the "same amount, fair shares", "how many without counting". Each child was also asked whether it was a different number or amount and if so which portion was more and which less and why he thought so. When a child gave nonconservation answers he was asked searching questions in order to clarify the problem, for example: "do you mean now there is a bigger number, and not just that it looks more", "if you counted would you count more", "was it the same number (or amount) before, was it more (or less) before", "does it really get to be more, (or less), how", "do the beads (or blocks, draughts etc.) change in number, what happens" etc. Both child and experimenter counted before and after transformations and reversed transformations. Four of the 5 basic explanations for conservation and the 4 types of experiences given in teaching conservation in Investigation Four were included in the present teaching procedure. The explanations given in the present investigation included the fact that it is the same material all the time, and that nothing has been taken away or added, that it looks different but really is the same amount, and that it can be put back as it was before. These explanations were made while the child observed or manipulated a variety of material transformations. The combination of verbalisation of reasons for conservation and counting (an external criterion) with active experience of transformations in a variety of situations was designed to help the child to appreciate the grounds for conservation judgments and to look for evidence of conservation. By using a variety of explanations and methods it was hoped to develop understanding in each child. Sixth, seriation problems were presented. Each child was asked to order objects by size, first in a single series and then in matched series. After ordering objects 'qualitatively' the child was asked to "build a stair" with unit blocks and to answer questions relating cardinal and ordinal numbers.

Thus, in teaching the four children, standard varied experiences and explanations were given for 6 basic types of problems. The control group children were not given any special treatment; they knew the experimenter well and the prior investigation had indicated that individual attention without specific conservation teaching did not result in increased understanding of conservation problems.

A detailed record was kept of each child's responses in the problem situations and a clearer picture of the development of understanding emerged from a study of these individual cases.

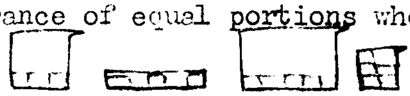
The first child, Gail, 12 years old and in Class 2, was reported by her teacher to be the very poorest in all number work. She was unable to do any addition or subtraction without counters and was totally confused by numerical problems. She reacted to most problem situations with fear and she clearly did not believe she could cope with them.

1 At the beginning of the teaching session, Gail hesitantly but correctly made comparison judgments for equal and unequal numbers of beads in both similar and dissimilar shaped containers e.g.  and  She took the beads out

to count them. For the dot distributions, however, Gail made incorrect though consistent purely perceptual judgments; she judged longer rows to be greater in number, e.g.  and  and rows with the same extremities to be equal in number, e.g.  When the experimenter suggested that she count the dots to find out the number in each row, Gail did so correctly but remained confused until the experimenter clarified the distinction between number and length. The experimenter asked Gail to "point to the row which has more (in) number of dots" and then, separately, to "point to the row which is longer". After this procedure was repeated several times for different dot distributions, Gail was able to make correct number comparison judgments for all the dot distributions. She carefully distinguished "more (in) number" from "longer" etc. For different arrangements of the same numbers of blocks, e.g.   and  , Gail made correct equality judgments.

2 In the one to one exchange (correspondence) situation, Gail was completely confused by questions about the number of sweets and pennies. She said she did not know if it was the same number, and, consistently, she said she did not know if there were more sweets or more pennies. After repeating the exchange of one sweet for one penny, Gail said there was a different number of each but she was not sure which was more. At this point the experimenter directed Gail's attention to the fact that one penny was given for each sweet so that two pennies 'bought' two sweets, three 'bought' three and so on up to 10 'buying' 10. The exchange was repeated slowly several times and after each sweet was 'bought' the experimenter asked Gail if there were the same number of sweets as pennies in each collection. In this way Gail began to recognise equality at each step of the exchange and ultimately for the completed exchange although she could not explain <u>why</u> the numbers must be equal.

By this stage of the teaching Gail was becoming more confident. She correctly matched one egg to each eggcup and then one to one counters in rows and draughts in piles; she did this perceptually and did not count. When the experimenter asked her to count and to select specified number of blocks Gail was able to do so correctly for 6, 11, 12 and 20 blocks. She was also able to do the simple classification problems presented.

3 Gail approached the creation of equality and inequality problems by putting one unit cube in one share each time she put one in the other; she did not count the unit cubes and was not able to create portions unequal by numbers more than one. In creating equality, Gail was not deterred by the different appearance of equal portions when in dissimilar containers, e.g. ; when questioned, she was confident she had shared the cubes equally. She was able to create these equalities using all of a given number of cubes, but she was not able to create inequalities by specified numbers, except by one which she did by giving one to each portion and then one extra to the first portion. Even with help Gail was unable to make portions unequal by 2, 5, or 7. When the experimenter created the inequality, Gail counted and recognised that there were different numbers in each portion but she was confused about how many more were in one portion than in the other and she did not learn to create the inequalities herself. Gail could not appreciate that by adding 2 or 5 or 7 to equal portions the resulting portions were unequal by those numbers. It was clear here that Gail's biggest problem was not overreliance on perceptual appearances but was a general inability to cope with even simple numerical problems. The experimenter moved on to the next problem when she thought that Gail would not benefit from continued teaching in the present problem situation.

4 Gail recognised that the numbers were different when a counter or draught was taken away or added to one of two previously equal rows or piles. She recognised which portion became more and which less and in each case she explained why, e.g. "you put another on", "you took one away". Thus, immediately before she was presented with conservation problems and the argument for equality that unless something is added or taken away the number remains the same, Gail was actively recognising the effect of addition and subtraction.

5 In the identity conservation situations, Gail recognised the continuing equality in number of beads and blocks but she gave no reasons for conservation. After each transformation of the single portion present, Gail said the number was the same but gave no explanation why this was so. Gail simply said "I can tell, I don't know how", or "it just looks the same" or "it looks like that way". When asked what would make it a different number, Gail suggested taking a block away and at this point the experimenter introduced the explanation for conservation that nothing had been taken away or added.

Gail did not recognise conservation of amount for either the rubber band when stretched or the water when poured. The experimenter therefore encouraged Gail to make and reverse the transformations herself. While Gail manipulated the materials the experimenter explained that it was the same rubber band or water all the time and so it could be put back just as it was before. The emphasis on the identity of the material in the identity or single portion conservation situations particularly helped Gail; this was evidenced by the fact that, after carrying out several transformations and reversals of the materials, she began to recognise and explain the continuing equality of amount in terms of the sameness of the material.

In the equivalence conservation situations, Gail did not at first recognise the continuing equality. She said the spread portions were more in number until she counted before and after transformations and manipulated reversibility. At this stage the experimenter repeated the identity and reversibility explanations for conservation. Eventually by predicting, before transformation, that the number would stay the same Gail began to recognise that the number did not change, that there continued to be "enough - one each". She thus developed a recognition of equality which she maintained in the face of perceptual changes with actual transformations. Gail recognised conservation when one of two piles of draughts was rearranged; she explained "I can tell by the same draughts are on". When one set of 12 beads was transferred to a different container Gail again recognised conservation and said "they got the same number before". In the inequality conservation situation Gail recognised the continuing inequality but she was unable to explain why; the experimenter therefore helped her to describe the situation, transformation etc. until she suggested "it is more like before it was". When one of the pair of rubber bands was stretched Gail recognised conservation and explained "it's the same one". The experimenter again emphasised the distinction between the actual amount of material and its appearance. Finally, Gail recognised conservation of liquid amount and said "I can tell it's the same water, I can tell by the water".

Gail thus gradually developed understanding of conservation. She appeared to be helped most by the emphasis on the identity of the material particularly in the identity conservation situations but it was the variety of experiences and explanations that provided the necessary basis for her understanding of number and its conservation.

6 With guidance Gail was able to create a single series of up to 10 Cuisenaire rods and insert rods into an incomplete series. Again with guidance she created a series of dolls and corresponding sticks. Gail had no understanding of ordinal numbers, could not relate cardinal and ordinal numbers, but the experimenter did not attempt to develop such understanding at this stage as Gail had already been working for 90 minutes.

A second child, Paulette, 13 years old and in Class 4, was reported by her teacher as being "hopeless, the very worst" on arithmetic. She could only do the simplest addition and subtraction and could not solve even the simplest numerical problems. When faced with such problems she became silly, she turned her face away and giggled. She frequently expressed her great dislike of arithmetic.

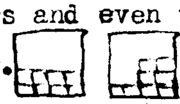
1 At the start of the teaching session, Paulette made correct comparison judgments for beads in similar containers; she counted correctly the equal and unequal portions. But when the beads were in dissimilar shaped containers she did not make correct judgments in either the equality or inequality situations, though her responses were consistent. Paulette

said there were more beads in the tall thin tube both when the numbers were equal, 6 and 6, and when there were in fact fewer in the tube, 6 while there were 8 in the other container. She made these judgments perceptually and did not count the beads. When the experimenter suggested she count the beads in each container, Paulette did so but became confused and insisted there were more in the tube even on recounting. The experimenter did not intervene at this point. When Paulette compared the number of dots in different rows she again made incorrect though consistent judgments. Like Gail, Paulette based her judgments entirely upon the extremities of the rows and judged longer rows to be greater in number and rows of the same length to be equal in number. Paulette did not count the dots in the different distributions and was entirely confident that her purely perceptual judgments were correct. Even after the experimenter encouraged her to count the dots, and not rely on perceptual appearances, Paulette insisted that the longer rows were more in number. At this point the experimenter had Paulette concentrate on the  distribution and emphasised the distinction between number and length. After repeated explanation Paulette learned to separate "more (in) number" from "longer". Paulette began to recognise "this row has more by number of dots" but "the other row is longer" and then that "the other row is longer but it has the same number of dots as this row" and finally that "the rows are the same long but that one has more by number of dots". She thus ultimately understood and correctly applied the distinction between number and length. Then for the different arrangements of the same numbers of blocks, Paulette, like Gail, made correct equality judgments.

2 Although Paulette had made more mistakes in the comparison situations than Gail and had very reluctantly accepted the need for counting, she was less confused by the one to one exchange (correspondence) situation than Gail had been. Paulette counted the sweets and pennies after the first exchange as she did not immediately recognise that the number must be the same. She had to count after repeated exchanges until the experimenter pointed out the one for one, two for

two etc. up to 10 for 10 correspondence. After each sweet was 'bought', the experimenter asked Paulette "have you the same number of sweets (pennies) as I have pennies (sweets)" until Paulette, like Gail, began to recognise equality without counting at each step of the exchange and finally for the completed exchange. Paulette, again like Gail, could not explain _why_ the numbers must be equal but she confidently maintained that none of either sweets or pennies could be 'left over'.

Paulette correctly matched eggs and eggcups, counters in rows and draughts in piles; she created these one to one correspondences perceptually and did not count. Like Gail, Paulette did not count in the provoked and unprovoked correspondence situations but she did count correctly up to 20 when asked and also selected required numbers of blocks for the experimenter. Paulette likewise correctly classified the drawn shapes by number.

3 Next, Paulette created equal numbers in similar and dissimilar containers; she did this by counting 6 unit cubes into one container and then 6 into the other, or 10 into one and 10 into the other. In creating these equalities, however, Paulette was very worried by the different appearance of equal portions when in dissimilar containers and even when piled differently in similar containers e.g.  ; Paulette was not at all sure the numbers were the same even though she had counted the unit cubes into each container. She said "they look different" and recounted one portion and then the other in every case. When checking her creation of equal numbers in dissimilar containers, Paulette became very confused and after she had recounted several times and was still not sure that she had shared the cubes equally, the experimenter encouraged her to rely on counting and not be distracted by perceptual differences. The necessary distinction between appearance and reality was made. Paulette came to realise the need to avoid purely perceptual judgments and began to depend on counting. The resolution of conflict in these creating of equality problem situations noticeably affected Paulette's attitude and understanding; she became more

open-minded and appreciated the value of counting and not relying solely on perception. Her biggest problem had been her over-reliance on perceptual appearances.

Paulette was not able, however, to create portions unequal by specified numbers. Although she had become able to create equalities not only using all of a given number of cubes but also by counting out specific numbers, she could not create portions unequal by specific numbers, not even by one. When asked to "put one more in this glass than in that one," Paulette counted 10 into each container and then took one from the first container and put it in the other saying "now you've one more". She thus created unequal portions but not portions unequal by the specified number. Paulette was also unable to make portions unequal by 2, 5, and 7 when asked to do so, either in containers or in shares. She had no idea how to deal with this problem. Like Gail, Paulette counted and recognised the inequalities when the experimenter created them but she was not clear how many more were in one portion than in the other and she could not create those particular inequalities herself. Because Paulette had already been working for approximately an hour and because the experimenter felt that Paulette would benefit more from teaching in the conservation and addition/subtraction situations than from any further teaching in the creation of inequality situation , the experimenter moved on to the next problems.

4 Paulette, like Gail, recognised the effect of addition and subtraction ; she said that the numbers were different because one counter (or draught) was "taken out" or "put on". Paulette recognised that taking one away meant there was less and adding one meant there was more; upon this understanding the experimenter, in the immediately following situations, built the argument for conservation that because nothing had been taken away or added the number (or amount) must be the same.

5 In the identity conservation situations, Paulette recognised the continuing equality after every transformation of the single portions present but at first she gave no reasons for conservation. For the container of beads moved vertical to

horizontal and vice versa, Paulette said the number was the same but gave no clear explanation why this was so. To support Paulette's judgments the experimenter introduced the explanation that nothing had been taken away or added. Paulette appreciated this explanation for conservation and when beads were transferred to a different container, she recognised conservation and explained "you put them all in there". When a single collection of blocks was bunched, spread or covered, Paulette again recognised the continuing equality of number but gave no reason for conservation until the experimenter re-emphasised that nothing had been added or taken away. Similarly, Paulette recognised the continuing equality of amount when a rubber band was stretched and when water was poured but at first gave no reasons for conservation. After she manipulated and reversed the transformations herself while the experimenter explained that it was the same material all the time and so it could be put back just as it had been before, Paulette began to give reasons for conservation of amount, e.g. "you just pulled it, it will put back," "the water will tip back".

The presence of a single portion only, in the identity conservation situations, directed Paulette's attention to the identity of the material transformed, eliminated the perceptual distraction of a comparison object and facilitated her recognition of conservation.

In the equivalence conservation situations, Paulette recognised the continuing equality of eggs and eggcups but when asked why the number was still the same she merely described the transformation "they were spaced", and gave no real explanation of conservation. Paulette recognised the continuing equality in this horizontal provoked correspondence situation but she did not do so in the following vertical unprovoked situation, until the experimenter reminded her that all the draughts were still there, none had been taken away or added. The experimenter asked Paulette to count the draughts in the different portions before and after she (Paulette) manipulated and reversed the transformations and then to predict before transformation that the number would stay the same. Paulette thus developed recognition of conservation of number; she explained "it's the same number, they counted the same before". When beads were transferred to different containers, Paulette recognised conservation for both equal and unequal numbers; she said "you tipped all of 'em in there" and "you tipped all of the more in". In the next situation, however, Paulette did not immediately recognise conservation of amount when one of a pair of rubber bands was stretched. But as soon as the experimenter drew her attention to the distinction between appearances and the actual amount of material, Paulette again recognised and gave reasons for conservation, "you just pulled it, it goes back". Finally, when one portion of water was poured into a different shaped container, Paulette recognised conservation and explained "you tipped it all in".

Thus Paulette, like Gail, developed understanding of conservation gradually. Both children needed the variety of experiences and explanations given in the teaching, though their understanding developed in quite different ways. Paulette was helped most by the emphasis on the reality underlying perceptual appearances where Gail had been helped most by the emphasis on the identity of the material. In both cases the single portion conservation situations facilitated their understanding.

6 In the seriation problem situations, Paulette had the same difficulty as Gail. With help Paulette, like Gail, created a single series, inserted missing rods into a series, and created corresponding series. Again like Gail, Paulette had no understanding of ordinal numbers, e.g. she pointed to the 10th step and called it the 2nd. Again the experimenter did not attempt to develop such understanding; Paulette had been working for 80 minutes.

The third child, Kevin, 13 years old and in Class 5, was reported to be painfully slow but able to do simple addition and subtraction. He was not able, however, to do simple numerical problems; such problems merely confused him.

Kevin was particularly distractable and missed the point in many situations through inattention. In teaching him, therefore, the experimenter used various supplementary methods of holding his attention so that he would follow through the simple logical arguments. For example, the experimenter encouraged him to talk out whatever came into his mind between each step of the teaching procedure so that he would approac the next step undistracted. The teaching given to every child was of course designed to capture attention through the variety of materials and problem situations, the active participation, manipulation and verbalisation, etc., but with Kevin extra efforts were made in order to overcome his lack of concentration.

1 Kevin, at the beginning of the teaching session, when assured there was no hurry, slowly correctly counted beads in similar and dissimilar containers to make comparison judgments; he correctly recognised the equal and unequal numbers of beads. Similarly, Kevin carefully counted dots and made correct comparison judgments for all the distributions. He did the same for different arrangements of the same numbers of blocks. Kevin relied entirely upon counting and gave consistent correct answers in all the comparison situations; he was very slow but accurate.

2 In the one to one exchange situation, Kevin did not at first recognise that the number of sweets and pennies must be the same. He said he did not know if the number were the same and, consistently, he did not know if there were more of one than of the other. But Kevin knew to count after the exchange to find out if there were the same number. Kevin had to recount after repeated exchanges; he could not otherwise recognise the equality of number. The experimenter, therefore, taught Kevin, as she had taught both Gail and Paulette, that one penny was given for one sweet, 2 for 2, etc. until 10 were given for 10. The exchange was repeated very slowly many times until Kevin without counting recognised at every stage that there were the same number of sweets 'bought' as pennies 'paid'. Kevin, like Gail and Paulette, developed

understanding gradually but, again like them, could not explain why the numbers must be equal.

Kevin established one to one correspondences by counting and not just by perceptual matching. In the provoked correspondence situation, he correctly counted the 9 eggcups and next 9 eggs for them; he then correctly matched 20 eggs to eggcups and checked by counting. In the unprovoked correspondence situations, Kevin correctly matched and then counted counters in rows, but he did not correctly match draughts in piles; he corrected these errors, however, by counting and adding the necessary draughts. Next Kevin correctly counted and selected specified numbers of blocks up to 20 and also did the simple classification problems.

3 Kevin created equal and unequal portions of unit cubes; he created equal numbers in similar and disimilar shaped containers and unequal numbers in containers and in shares. He did this by counting out one complete portion and then the other. In creating portions equal in number, Kevin relied entirely on counting and he was not worried by the different appearance of equal portions when in dissimilar containers. Although Kevin had to recount frequently to create equalities, when he had done so he remained confident he had made fair shares. In creating portions unequal by specified numbers, Kevin had great difficulty. He was able to create portions unequal by one by counting 2 cubes into one container and then 2 into the other, recounting, and then adding a third cube. He was not confident however that the portions were unequal by one until he recounted again. When it came to creating portions unequal by 5, Kevin started by putting cubes into each container but lost count and became confused before creating a difference of 5. He attempted to create the inequality several times but could not until he just counted 5 cubes into one container and left the other empty. Only in a similar way could Kevin create shares unequal by 2 and 7. The experimenter accepted this solution to the creation of inequality problems.

4 Although Kevin was in this sense able to create portions

unequal by specified numbers where Gail and Paulette were not, Kevin did not understand the addition and subtraction situations as well as they had. After a counter or draught was taken away or added to one of two recognised-as-equal rows or piles, Kevin had to count to tell whether the numbers were the same or different and which portion had more and which less. Kevin did not immediately recognise that taking away a counter or draught meant there were less in that row or pile nor that adding one meant there were more. When the experimenter spelled out the fact that adding or taking away a counter or draught makes the number different and that adding makes it more and taking away makes it less, Kevin recognised that there was no need to recount. On repetition of the addition/subtraction problems, Kevin recognised the effect of adding and subtracting counters and draughts, and he explained that the numbers were different because "you took one out" or "put one in" and "you put one more on" or "took one away". He no longer needed to recount before recognising that the numbers were different and which portion was more and which less.

Although Kevin had in practice previously added draughts to establish unprovoked vertical correspondence, added an extra unit cube to create unequal portions, etc., in the addition/subtraction problems he did not exhibit sound understanding of the processes until the effects of addition and subtraction were made explicit. Kevin had counted after every addition/subtraction transformation and had treated the transformed situation in isolation, just as he treated new comparison situations. When the experimenter emphasised the <u>processes</u> of addition and subtraction and linked the present situation to the past one, Kevin became free from his need to recount. In the addition/subtraction problems, Kevin had appeared to lack the reversibility important for conservation, that is Kevin had given no sign of considering the previous situation, until his attention was drawn to the processes and their effects on the <u>original</u> portions. Before moving on to the conservation problems, the experimenter made sure that Kevin understood the effect of addition and subtraction as such understanding is a basis for the conservation understanding that unless something is added or taken away the number remains the same. Likewise the experimenter made sure that Kevin attended to and retained awareness of situations as they were before transformation as a basis for recognising reversibility and conservation.

5 Kevin at first recounted in the identity conservation situations; he could not otherwise recognise the equality. The experimenter therefore pointed out in each number conservation situation that nothing had been taken away or added and she encouraged Kevin to make and reverse the transformations himself. The experimenter also explained that it was the same beads or blocks all the time and so they could be put back just as before. Then she asked Kevin to predict before transformation whether the number would remain the same. Finally Kevin recognised the continuing equality of number without counting. Kevin gave no reasons for conservation but he recognised the continuing equality of the single portion in the rubber band and water transformation situations as well as in the number conservation situations. When asked why he thought the amount the same, he simply described the transformation, "you pulled it," or "you poured it", etc.

The presence of a single portion only and the emphasis on the identity of the material did not seem to have the facilitating effect for Kevin that it had for both Gail and Paulette. Kevin did not initially recognise the continuing equality in the identity conservation situations any more than he had in equivalence conservation situations.

After Kevin had developed recognition of continuing equality and understood without needing to recount that there was no change in number or amount in the identity conservation situations, he recognised this in the equivalence conservation situations as well. Kevin recognised immediately that there was the same number or amount after every transformation in the equivalence situations. For the continuing equality of number after bunching and spreading in the provoked correspondence situation, Kevin gave no explanation; he simply said "it's just the same number". The experimenter then repeated the identity and reversibility explanations for conservation and asked Kevin to demonstrate the reversibility. The experimenter did not ask Kevin to count nor did she emphasise the distinction between appearance and reality in this way because Kevin had been overdependent upon this external criterion right from the beginning and had only gradually given up recounting unnecessarily.

Kevin recognised and gave reasons for conservation in all the subsequent equivalence situations; he gave an increasing number of explanations for his judgments. In the unprovoked correspondence situation , Kevin explained "it was just the same number before you put them (pointing) down". The experimenter added that he could put the draughts back the same way and asked him to do so. Kevin next recognised conservation of equal numbers of beads and explained "there were 12 before in there and in there (pointing), they counted the same before, and you can do this (demonstrates reversibility)". Likewise Kevin recognised conservation of inequality and explained "there wasn't the same number at first, they counted different before, there are still more - still 13 there (pointing)". For conservation of amount after one of a pair of rubber bands was stretched Kevin gave the explanation "it puts back, they were the same before". Finally, when water was poured into a different shaped container, Kevin recognised conservation and explained "you made the same amount of water in there as in there (pointing) and you just poured it there (pointing), the water was the same in there before, you can put it back in - see (demonstrates reversibility)".

Kevin thus developed understanding of conservation. In the identity conservation situations, he slowly began to recognise the continuing equality without needing to recount. The active manipulating and reversing of the transformations with no comparison object present directed Kevin's attention to the processes involved and to the fact that nothing was added or taken away from the original. The task of predicting equality did not allow recounting. Above all, the slow repetition of the varied explanations and experiences helped Kevin; like Gail and Paulette, Kevin developed understanding gradually through being presented with a variety of reasons, transformations, and materials.

In the equivalence situations, Kevin recognised the continuing equality and began to explain conservation in terms of reversibility; he justified his judgments both of continuing equality and inequality by citing the fact that the number or amount was the same or different before and that the transformation could be reversed. Where Gail and Paulette had explained conservation in terms of identity, Kevin gave reversibility reasons. Kevin's understanding developed in a very different way from Gail's and from Paulette's; he slowly became free from his need to recount and recognised the constancy of number. Unlike Gail and Paulette, Kevin had originally relied on counting and not on perceptual appearances, but despite this he did not recognise conservation until he was taught in the present investigation.

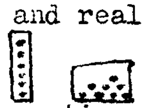
6 Kevin was able to create a single series of up to 10 Cuisenaire rods and to insert rods into an incomplete series, but he could not create corresponding series of dolls and sticks without help. Unlike Gail and Paulette, Kevin did understand ordinal numbers and the relation of cardinal and ordinal numbers up to 10/10th.

The teaching session ended after Kevin had been working for 30 minutes.

The fourth child, Robert, 11 years old and in Class 1, was particularly handicapped; he had a severe squint and noticeable hand tremor, both of which made performance in the teaching situations more difficult for him. Great care had to be taken that Robert could see and understand the problems presented and that he and the experimenter understood one another. This was sometimes difficult. Robert's teacher reported that he had no number ability of any kind; he could count but could not do any addition or subtraction, not even with counters.

1 At the start of the teaching session, Robert made correct and consistent comparison judgments for equal and unequal numbers of beads in similar shaped containers.

He took the beads out of each container in turn, counted them painstakingly into the experimenter's hands, and then put them back into the containers. He recognised where there was the same number, and where there was a different number he correctly pointed out which container had more. When the beads were in dissimilar shaped containers, however, Robert did not make correct judgments of either equality or inequality; when the numbers were equal he counted that the numbers were the same but still said that there were more beads in the tube and when in fact there were fewer beads in the tube he said that there were more. Robert correctly counted the beads in each container but became confused when appearances strongly contradicted reality.

When the experimenter found that Robert was unable to see to count and compare the dot distributions except with tremendous effort, she returned to the beads in different shaped containers to attempt to develop recognition of the distinction between appearance and reality. The experimenter had Robert concentrate on the  situation and repeatedly emphasised that one portion was more in number though in the other container the beads came up higher. Despite repeated explanations, counting, and questioning similar to that which had helped both Gail and Paulette in the dot distribution situations, Robert did not come to appreciate the distinction between number and apparent amount. Robert did not recognise that one portion was more by number of beads while the other came higher in the container; he did not learn to separate actual number from apparent size. Nor did Robert begin to understand and recognise the same number of beads were in different containers when they were stacked differently. He remained confused by the problems. The experimenter made every effort to discover and resolve Robert's difficulty but could not develop his understanding. Robert understood the wording of all the questions, as was evident in his responses in the beads in similar containers situations. (The experimenter avoided using the word "less" as Robert did not always use the word appropriately himself). Robert was clearly able to attend to 2 portions linked by quantity considerations and to give logically consistent answers to separate questions on sameness and difference, abilities again evident in the beads in similar containers situation . Even in the beads in dissimilar containers situation, Robert responded consistently though incorrectly; when he said the numbers were different he cited which portion he thought more and insisted they were not the same. Though he contradicted himself by saying the number was different immediately after counting the same number, Robert consistently chose the portion in the tube as more in number and gave a reasonable explanation for his choice; "there are more beads - they are higher". Counting did not help Robert to recognise the equality of number in dissimilar containers; he did not bring it to bear in making his judgments and he gave no sign of being aware of any contradiction in his responses. Because Robert was making no progress and was losing interest in the problem, the experimenter moved on to the next comparison situation.

For the different arrangements of the same numbers of blocks, Robert counted carefully and recognised the equality of number.

2 In the one to one exchange problem, Robert said there were more sweets than pennies and when asked why he thought the number different he said because the sweets were "rounder". The experimenter attempted to direct Robert's attention to the number not size nor distribution of the sweets and repeated the exchange slowly emphasising that one penny was given for one sweet, 2 for 2, etc. up to 10 for 10, but Robert still did not think the number of sweets and pennies the same. Consistently but incorrectly, Robert said the number was different, not the same, and that there were more sweets. As in the beads in dissimilar containers situation, Robert persisted in basing his judgments on some aspect other than number; number simply did not become his over-riding consideration. In the exchange situation, Robert seemed to base his judgments on the global quantity or size of sweets versus pennies and could not be brought to distinguish number from overall amount or perceived size, or at least he did not

attend to number alone when more than 3 sweets and pennies were involved. Robert did not learn to recognise equality at each step of the exchange and never did for the completed exchange, although he was given the teaching effective for Gail, Paulette and Kevin. Robert recognised the equality for the exchange of up to 3 sweets and pennies but for no more. Again when the experimenter felt that continued teaching in the same situation would be fruitless, she introduced the next problem situation.

Robert correctly matched eggs to eggcups, counters to counters in rows, and draughts to draughts in piles. He did this perceptually and very slowly and he did not count. When the experimenter asked him to count and to select specified numbers of blocks, Robert did so correctly for the numbers up to 20. He also did the simple classification problems correctly, but only with the greatest effort because of his difficulty in seeing the drawn shapes.

3 Next, Robert created equal numbers in similar containers by counting 6 (or 10) unit cubes into one container and then a corresponding 6 (or 10) into the other. He was not, however, able to create equal numbers in dissimilar shaped containers. The experimenter helped and encouraged Robert to count and rely on counting and not worry about the fact that "they look different" when he had counted that "they really are the same number". Here again she tried to help him understand the distinction between actual number and perceptual appearances by, for example, supporting his correct counting and suggesting he depend on what he so exactly counted out, as he only need consider the number in trying to make the fair shares. But Robert did not come to rely on counting; he continued to base his judgments on general appearance. When he attempted to create equal numbers in different containers, Robert counted 6 (or 10) into the first container and then counted a different number into the other container until he was satisfied by looking at them that they were fair shares. When asked if there were the same number in each, he confidently said there were.

Robert was not able to create portions unequal by specified numbers. When asked to give one or 2 or 5 or 7 more unit cubes to one portion than to the other, Robert started to count the cubes into a single portion, continued counting for a short time, dealt only with this first portion, stopped and looked up blankly. Robert had no idea how to proceed with the problem, so the experimenter tried to help him by demonstrating how to create portions unequal by the specified numbers (e.g. by creating equal numbers and then adding one or 2 or 5 or 7 to one portion). Robert recognised the inequalities created both in the similar containers and in shares; he counted each portion and correctly chose which portion had more, but he did not recognise how many more were in one portion than in the other. Nor did Robert create the inequalities himself when asked again to try to do so; he behaved exactly as he had the first time he tried. The experimenter moved on to the next problem when she felt Robert would not benefit from further teaching in the present situation.

4 In the addition/subtraction situations, Robert recognised that the portions were no longer equal after one counter or draught had been taken away or added. He said the numbers were different when one counter was subtracted but he said he did not know which row had more. When one counter was added, Robert incorrectly said the row with one less had more. The experimenter pointed out that adding a counter made more in the row and asked Robert to count the number of counters before and after one was added. Robert did this correctly. The experimenter then repeated the addition transformation but before asking Robert which row had more, she asked him which row had had another counter added. Robert correctly said which row had had the counter added and when asked, also said it had more. This process was repeated 2 more times and Robert responded correctly. Then the intermediate question, which row had had a counter added, was omitted and Robert continued to recognise which row had more. When one draught was added to or taken away from one of two recognised-as-equal piles, Robert correctly

recognised which pile had more as well as that there was a different number in each. Thus Robert began to recognise the effect of addition and of subtraction, but when the experimenter asked him to try to explain why he thought what he did he could not do so. Robert did not express the fact that adding one makes more, though the experimenter had repeatedly explained that this was the case. Nor, predictably, did Robert explain that taking one away makes less. The experimenter did not include the explanation that subtracting one makes less because questions could be clearly put in terms of more as well as same and different. If the experimenter had planned to develop Robert's understanding of the word "less" she would have tried to do this at a preliminary stage before introducing the word in relation to transformations, i.e. she would have first introduced "less" in a static comparison situation.

5 Robert developed in understanding the effect of addition and subtraction and the experimenter tried to build upon this in teaching conservation. In the identity conservation situations, Robert did not recognise that the number of beads was the same after their container was moved from vertical to horizontal and vice versa. He said the number was different but he was hesitant, and when he was asked, he could not say which way he thought there were more beads. The experimenter therefore asked Robert if any beads had been added or taken away and he recognised that they had not. The experimenter repeated that none had been added or taken away just as Robert had said and explained carefully that it was the same 5 (or 8) beads. When the transformations were again repeated Robert recognised the continuing equality; he confidently said the number was the same but he did not explain why he thought so.

When a single portion of beads was transferred to a different shaped container, Robert did not recognise the continuing equality in number. The experimenter asked and helped Robert to make and reverse the transformations himself and while he manipulated the materials, the experimenter explained that it was the same beads all the time and so they could be put back just as they were before. This procedure was repeated several times. Robert, however, persisted in saying there were more when the beads were in the second container "cause they roll round". Finally, when Robert began to lose interest in the present materials, the experimenter moved on to the next material transformation.

Robert again did not recognise conservation of number when blocks were bunched or spread. He chose the more extended portion as greater in number in both cases. When he was questioned and encouraged to say exactly what he meant and why he thought what he did, Robert said the number itself was bigger, and that the blocks would count more, and that it got more "cause it got bigger". Even when he counted before and after he moved the blocks, Robert continued to say the number was different; he did not recognise the significance of his counting. When, however, the blocks were merely covered by an opaque or translucent box, Robert said the number would continue the same.

Robert did not recognise conservation of amount for either the rubber band when stretched or the water when poured. He said the rubber band was "morer" when it was stretched and the water was "morer" before it was poured. With the experimenter's help, Robert made and reversed the transformations several times himself but again after repeated explanations of identity and reversibility, Robert still did not recognise conservation.

In the equivalence conservation situations, Robert continued to give nonconservation answers despite all the explanations and experiences the experimenter had previously found effective in developing understanding of conservation. Robert consistently made incorrect judgments and was resistant to all attempts to get him even to predict continuing equality. When asked "do you mean now there is a bigger <u>number</u>" Robert said yes. He sometimes said it would count more and he sometimes said he did not know.

He was confused by the question "was it the same number (or amount) before" and gave no clear answers. But when asked how it gets to be more, he confidently said "it gets alotter, bigger" etc. Despite the variety of experiences and explanations given during 80 minutes of teaching, Robert remained a nonconserver still.

6 In the seriation problem situations, Robert was able to create a single series of up to 10 Cuisenaire rods and to insert rods into an incomplete series, but he could not create corresponding series of dolls and sticks even with help. Nor did Robert understand ordinal numbers and the relation of cardinal and ordinal numbers up to 10/10th.

Robert's teaching session ended after he had been working for 90 minutes.

By the end of their 80 or 90 minute teaching session, three of the four previous nonconservers of number had developed understanding of conservation; one child still had not developed such understanding.

(iii) Post-testing.

The post-test included problems on conservation of number, substance and weight. The number conservation situations were familiar from the pre-testing and the teaching but new materials and unequal portions were introduced. The first substance conservation situation was familiar from the teaching but again unequal portions were introduced and the second substance conservation situation had not been included in either the pre-testing or teaching of the present investigation. Nor had either of the weight conservation situations been included in the pre-testing or teaching. Thus, generalisation of understanding of conservation was tested by using new materials, inequality situations and different attribute problems.

For number conservation, after the beads had been transferred as in the pre-test, equal and unequal portions of nuts, new material, were transferred to different shaped containers, containers unlike those used for the beads. Then, after the eggs and eggcups in provoked correspondence had been bunched and spread, equal and unequal portions of toy houses, new material in unprovoked correspondence, were regrouped.

For substance conservation (see Piaget (1952) Chapt.1, and Piaget & Inhelder (1941) Chapt. 1), after one of two equal portions of water had been poured into different shaped containers, unequal portions of water were so poured, and then equal and unequal portions of plasticine, new material, were rolled or cut into quarters.

Finally, for weight conservation (see Piaget & Inhelder (1941) Chapt.2), equal and unequal portions of rice were transferred to different containers, containers unlike those used in the number and substance situations, and then equal and unequal portions of plasticine were flattened or cut into thirds.

The standard post-test was given one week and again two weeks after the children had been given instruction. Both the instructed and the control group children were given the same test. Each child was seen alone for about 20 minutes. The criterion for understanding conservation was recognition of continuing equality after transformations in shape accompanied by explanations of conservation in terms of identity or reversibility or exact compensation.

When post-tested, three of the four children given instruction recognised and gave reasons for conservation in all of the number, substance and weight situations. The fourth child, Robert, still did not recognise conservation in any of the post-test situations. The control group children likewise did not recognise conservation in any situation.

Gail, Paulette and Kevin had developed a generalised understanding of conservation; this was evidenced in their recognition and explanation of conservation of weight as well as substance and number in unfamiliar and inequality situations as well as in familiar situations. Their understanding of conservation was not limited to the number or particular substance conservation situations in which they had been taught. Nor was their recognition of conservation merely an automatic response; they recognised inequality and its conservation. They had clearly learned more than a verbal formula. Gail usually explained conservation in terms of the identity of the material, Paulette gave a form of the nothing has been taken away explanation and Kevin pointed out the possibility of reversibility; all three children mentioned more than a single reason for conservation. The reasons the individual children gave on both post-tests were similar to those they had given during their teaching session.

There were noticeable individual differences in the three children's approaches to the conservation problems as well as in their explanations of their conservation judgments. Gail watched carefully that it was the same beads or nuts or eggs and cups or houses or water or plasticine or rice, and she explained that it was the same material before and again that it was the same material all the time. Gail recognised conservation in all the situations and said, for example, "they got the same number (beads, nuts, water, plasticine, rice) before", "it's the same eggs (houses, plasticine, one, rice)", "I can tell it's the same water, I can tell by the water", "it's still more like before", "more plasticine still weighs more".

Paulette paid close attention to see that the experimenter kept all that she had at the start and then confidently pointed out that nothing was taken away and it was the same before. Like Gail, Paulette recognised conservation in all the situations. She said, for example, "you turned (tipped) all of 'em (the beads, nuts, water) in there", "you kept all of it", "I saw they were the same before", "I looked at the other one and knew they both weigh the same before (in the bag)", "it counted more before", "you tipped all of the more in".

Kevin relied on the fact that the portions were made the same before and could be put back the same. He also mentioned compensatory relationships but he did not express these clearly. Kevin, like both Gail and Paulette, recognised conservation in all the situations. He said, for example, "there were 8 in there and in there before," "there was the same number at first", "they counted the same before", "you can move (put) 'em back", "puts back, proves it's the same", "you put the same water in there as was in there", "one's bigger, the other's a wider jar, so it's the same", "one's bigger and the other's bigger and they were the same before", "the rice weighs the same, the bowl and bag weigh different", "there are still more, still 9".

Robert, unlike Gail, Paulette, and Kevin, made incorrect (though consistent) judgments throughout the post-test; he said the portions were different, that they were not the same, and he chose one as greater in each case. Robert attended to the different attribute situations, understood and used appropriately the terms of the questions, and gave coherent and not totally irrelevant explanations for his judgments which were more than mere guesses; but he made no conservation judgments.

Robert created or chose equal portions to begin with, but he failed to recognise the continuing equality of number, substance, and weight after one of the portions was transformed in shape. He said, for example, "the tubes's got more cause it's long", "the glass has more, it looks more", "more in that row, it's spreaded", "my glass has more to drink, it looks bigger", "more in your dishes, 'cause more", "that's more plasticine cause it's long", "more in those bits 'cause it got more", "the bag of rice weighs more 'cause it's alot", "the ball weighs more 'cause it's round". After the inequality transformations, Robert's choices directly contradicted the actual situation; he said the lesser portion was greater.

Robert usually but not always made the same choices on both post-tests; except where petri dishes and plastic bags were used he chose the same portions as greater on both tests. Robert did not choose exclusively either the original or the transformed portion as greater; he centered on some aspect or aspects of the particular transformations in making his choices, but if there was a common perceptual basis for his choices, it was not clear to the experimenter.

The control group children likewise made no conservation judgments. Like Robert, they understood the problems as the experimenter intended them and they made consistent but incorrect judgments.

III DISCUSSION

This investigation showed that a generalised understanding of conservation can be developed in educationally subnormal children who are initially without the degree of understanding indicated by conservation of number. The investigation likewise provided a clearer picture of the development of individual understanding of conservation.

Three of four children who had been total nonconservers at the start of their teaching session learned to recognise conservation and could explain their reasons when they did so. These children learned what to look for and attended to the relevant aspects of the situations; they made the necessary distinctions and related things which they had not related before.

The three children were aware they had learned something; they approached the problem situations with a new confidence. Gail's attitude to new problems became positive; she tried without fear. Paulette admitted that just looking at the present situation was not enough; she recognised there were other considerations. And Kevin recognised that he did not need to recount; he thought back to the original situation. In other words, the children developed in more than understanding of conservation. It was hoped that they would carry over these more effective attitudes and approaches to quite different problem situations.

There were noticeable individual differences in the children's development of understanding and these will be considered later in the discussion, but certain aspects of the teaching were particularly effective for all three children who learned. The particularly effective aspects included the following: concentration on <u>number</u> in a variety of situations, separation of appearance and reality (especially in the comparison and creation of equality situations), and the related clarification of the distinction between more in number and longer (especially in the dot distribution comparison situation), juxtaposition of addition/subtraction and conservation transformations, and presentation of identity conservation situations before equivalence conservation situations. The children's active manipulation of more than reversibility was important; for example, their attempts to create equal numbers in different shaped containers very effectively developed their appreciation of the need to rely on counting, a familiar and simple external criterion, rather than on perceptual appearances. Guided observations and explanations of identity ('qualitative' and 'quantitative') and of reversibility in a variety of situations graded in degree of difficulty enabled the children to explain as well as to recognise conservation. Steady encouragement as well as patient correction and repeated explanation developed their confidence that they <u>could</u> understand the problems.

The children found some problems especially difficult and others quite easy. Relative difficulty, of course, was influenced by the stage in the teaching and the presentation of the problem, but the children found creating inequalities, relating cardinal and ordinal number, recognising equality in the exchange situation, and comparing the dot distributions especially difficult whereas they found counting, making 1 to 1 correspondences, recognising conservation of a single portion covered by a box, and comparing numbers in similar containers quite easy.

Certain aspects of the teaching contributed little to the children's understanding of conservation and probably could have been omitted; the seriation problem situations, in particular, were not necessary. Likewise the order in which the teaching situations were presented probably could have been different; the exchange situation, for example, could have been presented later. The investigation, however, was an exploratory one and the aim was not to isolate essentials nor to find any one best sequence of steps for teaching. The purpose was to develop the understanding of the least responsive non-conservers by providing for their different needs. The teaching method used was not necessarily the best way to develop a generalised understanding of conservation in these children but it was an effective way.

The amount of teaching given in the different situations was adapted to the individual children's needs. Different children's understanding improved most in different situations and for different reasons. Gail was helped to overcome her general confusion and fear in number conservation situations through having her attention directed to the identity of the material after diverse transformations and through being encouraged in her small successes in simpler problem situations. The clarification of the relevant considerations especially in the identity conservation situations and also the juxtaposition of addition/subtraction problems and conservation problems were particularly effective in developing Gail's understanding of conservation. Paulette was helped most by the distinction made between 'more in number' and 'longer' in the comparison of rows of dots situation and by the need to separate appearance and reality in the creation of equality in unequal containers situation. She had been less generally confused by number situations than Gail (e.g. in the exchange situation) but she had relied more strongly on perceptual appearances. The emphasis on the fact that nothing had been taken away, especially in the identity conservation situations, helped Paulette give up her complete reliance on present appearances. Kevin, in contrast to Paulette and also unlike Gail, did <u>not</u> base <u>any</u> of his judgments on perceptual appearance alone; he counted and then recounted after any transformation. He did not recognise continuing equality without recounting until he was given teaching emphasising reversibility and drawing his attention to the significance of addition/subtraction. Kevin was particularly helped by having his attention directed to the prior situations and to the actual transformations in the conservation problem situations and also by the explicit teaching given in the addition/subtraction problem situations.

Thus, Gail, Paulette and Kevin had different needs and developed understanding of conservation in different ways. (See the chapter appendix for the details of the individual children's responses to teaching). The three children differed in their original abilities (e.g. Kevin was more able than Gail and Paulette in the creation of inequality situation but Gail and Paulette were more able than Kevin in the addition/subtraction situation) and they developed understanding for different reasons (e.g. Gail attended to the identity of the material, Paulette to the fact that nothing had been taken away and Kevin to reversibility).

Robert did not develop understanding of conservation. It was not clear why he made so little progress during the teaching session. The only appreciable improvement was in his understanding of the effect of addition/subtraction. Even with extensive teaching he made no progress in the comparison, exchange, creation of equality and inequality, and conservation situations. The only continuing equality that Robert recognised was in the identity conservation situations when tubes of beads were moved horizontal or vertical or when blocks were covered. In these cases the beads or blocks were not themselves transferred or transformed, only containers were moved, and though Robert recognised the number was the same, he gave no reasons for conservation. Further study might reveal the source/sources of Robert's difficulty, for example what his criteria are in making his judgments, exactly what effect his perceptual and motor handicaps have on his development of understanding, etc. and this might enable more effective teaching. Further teaching might introduce larger clearer dot distributions or use blocks to replicate the teaching situation which, for Gail and Paulette, was so effective in clarifying the distinction between more in number and longer. Likewise, material changes in other problem situations might clarify Robert's understanding, for example, chocolate pennies of the same size as the other pennies might be used to direct his attention to number by eliminating some irrelevant differences in the exchange situation. Various other changes could be made and further experiences included to explore and clarify Robert's understanding.

The three children's development of understanding of conservation was gradual. Recognition of continuing equality without explanation of conservation developed before understanding of conservation for expressed reasons of identity or reversibility. There was no sudden radical change in the children's approaches to conservation problems. They amended their prior approaches, for example, Paulette still watched but she watched that nothing was lost rather than that the shape was the same, and Kevin still relied on counting but he remembered a prior count and did not recount. The understanding of conservation that the children developed, however, was a new understanding, as far as any understanding is ever 'new'; the teaching could not be said to merely activate existing understanding of conservation as the children had exhibited no prior understanding of conservation.

To conclude, the investigation showed that given fuller teaching, some children who do not initially recognise number conservation and who may not develop such understanding after being given brief teaching, can be helped to develop a generalised understanding of conservation. Such children were successfully taught using a general eclectic method; a variety of problem situations, experiences, materials and explanations provided for the children's different needs and they gradually developed understanding.

IV APPENDIX

Pre-testing Procedure for Investigation Five.

1a. Put the same number of beads in each glass, 8 in here and 8 in there (2 identical 100ml beakers and 16 beads of 2cm diameter)

Is there the same number of beads in each glass?

If you have this glass and I have that glass (pointing) have we as many beads as each other?

(After recognition of equality)

If I do this to mine (pour one beaker of beads into taller, thinner container)

What about now?

Is there still the same number of beads?

Do we have a different number?

Do we still have as many beads as each other?

Why do you think so?

(Repeat procedure using two sets of 12 similar beads but substituting low wide for tall thin container)

1b. Put out the same number of eggs as cups, make rows of 7 in each (7 2D cardboard eggs and cups)

Is there the same number of eggs as cups?

Are there as many eggs as cups?

(After recognition of equality)

If I do this (bunch eggs near the cups)

What about now?

Is there still the same number of eggs as cups?

Is there a different number?

Are there still as many eggs as cups?

Why do you think so?

(Put eggs back into cups and repeat questions for 11 eggs and cups spreading the eggs out far from the cups)

Post-testing Procedure for Investigation Five.

1a. Repeat pre-test 1

Repeat pre-test 1 substituting nuts in 2 50ml beakers — equal portions of 15, one portion transferred into a petri dish, unequal portions of 8 and 9, 8 transferred into a taller thinner container

1b. Repeat pre-test 2
Repeat pre-test 2 substituting toy houses - equal portions of 14, one portion regrouped, unequal portions of 7 and 8, 7 spread

2a. Put the same amount of water in each glass, make fair shares to drink (2 identical 50ml beakers)
If you have this glass and I have that glass (pointing) have we an equal amount to drink, fair shares?
Is there the same amount of water in each glass?
(After recognition of equality)
If I do this to mine (pour one drink into petri dish)
What about now?
Do we still have an equal amount to drink, fair shares?
Do we have different amounts?
Is there still the same amount of water?
Why do you think so?
(Repour drinks into original beakers and repeat questions pouring one drink into two petri dishes)
Repeat procedure using unequal portions

2b. Make balls with the same amount of plasticine each, equal amounts (2 strips of plasticine)
If you have this ball and I have that ball (pointing) have we equal amounts of plasticine, fair shares?
Is there the same amount of plasticine in each ball?
(After recognition of equality)
If I do this to mine (roll one ball into snake)
What about now?
Do we still have equal amounts of plasticine, fair shares?
Do we have different amounts?
Is there still the same amount of plasticine?
Why do you think so?
(Remake two balls and repeat questions cutting one plasticine ball into quarters)
Repeat procedure using unequal portions

3a. Choose two bags with rice which weigh the same, which are equal in weight (3 plastic bags of rice - 2 weighing approximately $\frac{1}{2}$lb each, 1 weighing approximately 2ozs)

Would yo hold these two bags (two identical bags of rice)
Do they weigh the same as each other?
Are they equal in weight? equally heavy?
(After recognition of equality)
If I do this (pour one bag of rice into bowl)
What about now?
Does the rice still weigh the same?
Does the rice weigh different?
Is your rice still equal in weight to mine? equally heavy?
Why do you think so?
(Repour rice into original bags and repeat questions
pouring one bag of rice into two jars)
Repeat procedure using unequal portions

3b. Choose two balls of plasticine which weigh the same,
which are equal in weight (3 balls of plasticine - 2 half
the weight of 1 large ball)
Would you hold these two balls of plasticine (two
identical balls)
Do they weigh the same as eac other?
Are they equal in weight? equally heavy?
(After recognition of equality)
If I do this to one (flatten one ball into pancake)
What about now?
Does it still weigh the same?
Does it weigh different?
Are they still equal in weight? equally heavy?
Why do you think so?
(Remake two balls and repeat questions cutting one
plasticine ball into three pieces)
Repeat procedure using unequal portions

Teaching Procedure and Results for Investigation Five.

KEY

✓	correct	R	with reasons
✗	incorrect	N/R	without reasons
✗ → ✓	corrected after teaching		

1 Comparison:

"same number/as many, different number/which more/ which less, how find out/would counting prove"

				G	P	K	R
2 similar containers	7	7	beads	✓	✓	✓	✓
	7	8	beads	✓	✓	✓	✓
2 different containers	6	6	beads	✓	✗	✓	✗
	6	8	beads	✓	✗	✓	✗
2 similar extremeties	7	7	dots	✗ → ✓	✗ → ✓	✓	–
	9	6	dots	✗ → ✓	✗ → ✓	✓	–
2 different extremeties	9	6	dots	✗ → ✓	✗ → ✓	✓	–
	7	7	dots	✗ → ✓	✗ → ✓	✓	–
2 different distributions	4+2	3+3	blocks	✓	✓	✓	✓
	4+4	7+1	blocks	✓	✓	✓	✓

2 Correspondence-exchange:

		G	P	M	R
"same number/as many, morepennies/more sweets, why"					
sweets for pennies	10 10	×→✓	×→✓	×→✓	×
provoked:					
"put out same number eggs as there are egg cups, put so just as many"					
eggs and eg cups	9	✓	✓	✓	✓
	20	✓	✓	✓	✓
unprovoked:					
"put same number counters out as I have, make row of as many as my row"					
counters	7 horizontal	✓	✓	✓	✓
	15	✓	✓	✓	✓
"make pile with same number draughts as in this pile, make pile of as many draughts as these"					
draughts	8 vertical	✓	✓	×→✓	✓
	12	✓	✓	×→✓	✓
cardination:					
"count and tell me the number of blocks here, find out how many there are"					
blocks	11	✓	✓	✓	✓
	20	✓	✓	✓	✓
"give me --- blocks"					
blocks	6	✓	✓	✓	✓
	12	✓	✓	✓	✓
classification:					
"put cards with same number objects on them together, put cards together that go together"					
shapes	3s	✓	✓	✓	✓
	7s	✓	✓	✓	✓

			G	P	K	R

3 Creation of equality:

"put the same number in each glass,
give each as many/fair shares, share equally"

			G	P	K	R
similar containers & unit cubes	6	6	✓	✓	✓	✓
	10	10	✓	✗→✓	✓	✓
different containers & unit cubes	6	6	✓	✗→✓	✓	✗
	10	10	✓	✗→✓	✓	✗

inequality:

"put --- more in this glass than in that one,
give yourself --- more than you give me"

		G	P	K	R
containers and unit cubes	1	✓	✗	✓	✗
	5	✗	✗	✓	✗
shares of unit cubes	2	✗	✗	✓	✗
	7	✗	✗	✓	✗

4 Addition subtraction:

"same number/as many, different number,
which more, which less, why think so,
same unless +/−, does taking some away
make it more or less, does adding some
make it more or less"

			G	P	K	R
2 rows counters	7	sub 1 from 1	✓	✓	✗→✓	✗→✓
	9	add 1 to 1	✓	✓	✗→✓	✗→✓
2 piles draughts	9	add 1 to 1	✓	✓	✗→✓	✓
	7	sub 1 from 1	✓	✓	✗→✓	✓

5 Conservation:

"what about now, same number/as many, different number, which more, which less, why, fair shares, how many without counting"

			G	P	K	R
	identity:					
beads vertical to horizontal		5	✓NR	✓NR	x→✓NR	x→✓NR
beads horizontal to vertical		8	✓NR	✓NR	x→✓NR	x→✓NR
beads jar to box		6	✓NR	✓R	x→✓NR	x
		12	✓NR	✓R	x→✓NR	x
blocks bunched		7	✓NR	✓NR	x→✓NR	x
blocks spread		10	✓NR	✓NR	x→✓NR	x
blocks covered		8	✓NR	✓NR	x→✓NR	✓NR
		15	✓NR	✓NR	x→✓NR	✓NR
rubber band stretched			x→✓R	✓NR	✓NR	x
liquid poured			x→✓R	✓NR	✓NR	x
	equivalence:					
eggs and eggcups	eggs bunched	7	x→✓NR	✓NR	✓NR	x
	eggs spread	10	x→✓NR	✓NR	✓NR	x
draughts	12 white	6+6	✓R	x→✓R	✓R	x
	7 black	4+3	✓R	x→✓R	✓R	x
beads in containers	eq	12 & 12 move	✓R	✓R	✓R	x
	uneq	12 & 13 move	✓NR	✓R	✓R	x
rubber bands	one stretched		✓R	x→✓R	✓R	x
liquid	one poured		✓R	✓R	✓R	x

			G	P	K	R
6 Seriation - single:						
"put sticks in order, biggest first, then one a bit littler, then littler and littler to littlest"						
Cuisenaire rods from disarray	4		✓	✓	✓	✓
	10		✓	✓	✓	✓
"put these extra sticks where they belong in order biggest to littlest"						
Cuisenaire rods to insert	1		✓	✓	✓	✓
	2		✓	✓	✓	✓
equivalence:						
"give big dolls big sticks and little dolls little sticks, biggest stick for biggest doll bit littler for bit littler till littlest for littlest"						
Sticks for dolls from order	4		✓	✓	✓	✗
reverse	10		✓	✓	✓	✗
disarrays	4		✓	✓	✓	✗
relation cardinal/ordinal:						
"build a stair like this one, how many blocks make --- step, what next step, how many blocks for it, what call highest step"						
Lego stair	4	4th	✗	✗	✓	✗
	5	5th	✗	✗	✓	✗
	10	10th	✗	✗	✓	✗

CHAPTER 7

CONCLUSION

In this concluding chapter, answers to the six central questions with which the research was concerned will be discussed. Various subsidiary questions which arose in the different investigations have been dealt with in the earlier chapters and will not be further discussed here.

Question 1: Can understanding of conservation be developed in educationally subnormal children by instruction? The answer is yes. In the five investigations, children whose IQs ranged between 42 and 77 and who were aged between 8 and 16 were successfully taught conservation of quantity. There was evidence that these children developed a genuine understanding of conservation and had not merely learned a rote or stereotyped verbal response. For example, the children made negative as well as positive judgments; in the inequality situations they asserted the portions were not the same and pointed out which portion continued to be greater. A judgment of sameness was not automatic. Further evidence of the genuineness of the children's understanding was the variety of their explanations for conservation. Individual children expressed their reasons in various different ways and often gave more than one type of explanation; likewise different children expressed their reasons differently and a wide variety of explanations was given. These explanations were not unlike those of the children who had developed conservation spontaneously. The experimenter's questions were worded differently for different attributes so no simple verbal cue was given; care was taken to avoid bias in the presentation of the problems. Thus it was evident that the children given instruction on conservation had learned with understanding.

The question whether understanding, which is developed as a result of teaching, is 'evoked' or 'created *de novo*' has been raised by various writers, e.g.,Inhelder, Bovet, Sinclair & Smock (1966), Kohlberg (1968), Beilin in Elkind & Flavell (1969), Gelman (1969). In asking whether conservation is 'elicited' rather than developed as a 'new strategy', these writers are making a distinction between the actualization of existing structures and the formation of new operational structures. The distinction however seems unhelpful and artificial. It seems unhelpful because the same distinction can be made with regard to the 'spontaneous' development of understanding of conservation; understanding developed in the course of everyday life is as likely to be an extension of some prior understanding rather than a new creation. It seems artificial because understanding of conservation develops gradually rather than as an all-or-none conceptual entity. If conservation, like other understanding, arises from various prior understandings, it may be both new and related to existing structures. Finally, unless the distinction is based on some specified behavioural differences, it is of little use in interpreting the results of studies attempting to teach conservation. If it were shown that a prior recognition of conservation, say conservation of number, was necessary before teaching of conservation were effective then there would be some evidence justifying a distinction. Investigation Five, however, indicates that such conservation is not a prerequisite, but this will be discussed fully later. Whether conservation is deemed 'evoked' or 'created de novo' in the five investigations, the children evidenced a new appreciation of conservation after being given instruction.

The investigations thus showed that there is no need to await the 'spontaneous' development of conservation in ESN children, but this does not mean it is necessarily possible to successfully teach all children regardless of their age and condition. There is likely to be some lower limit of necessary ability, but this remains to be defined.

Question 2: By what means can understanding of conservation be developed in ESN children? One way that this can be done is by giving children a large amount of varied relevant experiences and explanations in concrete situations. This general answer will be enlarged upon, but three preliminary points need to be made. (1) The investigations showed how understanding of conservation _may_ be developed, how children may be _helped_ to develop understanding; this is a separate issue from how conservation necessarily or generally develops. (2) Likewise, the investigations showed what sort of teaching method is effective for _many_ ESN children, which is a different question from why, or for what reason or reasons, individual children learn. (3) The investigations revealed what type of experience is important, but did _not_ isolate any essential ingredient or minimum condition.

The teaching procedures were based on close study of ESN children's performances on conservation problems as well as on analysis of what is involved in the conservation tasks themselves. The most important feature of the teaching procedures used in the different investigations was the variety of experiences and explanations. This provided for children's different needs and facilitated the development of broad understanding. Quite a full case for conservation was presented and children gradually developed understanding. Multiple embodiments of the same general principle developed a broad understanding and not just recognition of conservation in particular situations.

The various explanations for conservation, the identity of the material, that nothing had been added or taken away, the possibility of reversibility, that it was the same before, and the exactly compensating relationships, emphasised the reality underlying appearances. The children began to recognise the continuing equality despite immediate appearances and became aware of the inadequacy of purely perceptual judgments. They learned to select what was relevant for conservation and were not mislead by changes in appearance only. They developed understanding by observing and manipulating reversible transformations and by using external criteria or measures for equality while the experimenter explained the various reasons for conservation and encouraged their correct judgments and explanations.

A number of writers have discussed at length the possible sources of conservation, see for example Piaget (1952), Piaget, Inhelder & Szeminska (1960), Bruner et al (1966), Piaget (1968), Sigel & Hooper (1968), Elkind & Flavell (1969), Halford (1970). In the present investigations, no one experience or explanation was found to hold the key to conservation for all children. Understanding of conservation was not found to develop in an all-or-none manner, either spontaneously or during the course of teaching, and different children appeared to learn for different reasons. There was no evidence of a single source of conservation.

Question 3: Is the understanding of conservation developed generalised and durable? The answer is yes. After instruction children recognised and gave reasons for conservation in new material, inequality, and different attribute situations and they continued to make conservation judgments up to eight months later.

In Investigations One, Two, Four and Five children generalised conservation to a wide range of situations. So also did children in Investigation Three who, in a group, were given teaching similar to that in Investigation Two. When teaching procedures were systematically reduced however, in Investigation Three, children developed correspondingly less generalised understanding of conservation.

Conservation was generalised to attributes usually recognised as invariant earlier than the attribute taught. The understanding of conservation of volume developed was generalised to weight and substance situations and that of area to volume, weight, length, and substance situations. Conservation also appeared to be generalised to attributes later in the usual sequence. The developed understanding of conservation of number was generalised to substance and weight situations and that of weight to volume situations.

Thus the understanding of conservation developed in the different investigations was found to be generalised widely. Exploratory questioning of children taught volume conservation indicated that they were also able to create equal volume buildin s on different bases, and children taught number conservation learned to create equal numbers in unequal containers. The ability to create equalities which differ in appearance is a criterion for conservation which Piaget has emphasised, see for example Piaget (1967), and is one which could have been included in testing ESN children's understanding. However, tests for creation of equality like tests for transitivity tap understandings different from conservation and for practical purposes may be omitted when children clearly recognise and give reasons for conservation in a wide variety of problem situations.

A question that needs to be considered is why the understanding of conservation developed by instruction is generalised to all the other attribute situations on the post-tests when, as the pre-tests show, the understanding of conservation developed spontaneously is evidenced in some attribute situations before it is in others. Why is conservation so widely generalised after teaching when it develops sequentially otherwise? This is a difficult question and it is not fully answered in the present research. Certain points however can be noted. During the course of the teaching understanding of conservation did not develop in an all-or-none manner anymore than it does ordinarily. It was only gradually extended to include more complex attribute situations, though after full teaching there appeared to be an all-or-none recognition of conservation. A possible explanation for the widely generalised understanding of conservation evidenced after the single teaching sessions is the unusually concentrated assembly of problem situations and explanations of various reasons for conservation which would not normally be experienced in the course of development.

Finally, the understanding of conservation developed was found to be lasting as well as generalised. All the children who developed conservation retained their broad understanding over 2 or 3 post-tests 2 weeks to 8 months later.

<u>Question 4: Is there a uniform sequence in the 'spontaneous' development of conservation in ESN children?</u> The answer is yes. Investigations Two, Three and Four

confirmed the substance-before-weight-before-volume conservation sequence found by Piaget & Inhelder (1941) in normal children and by Inhelder (1943) in the mentally retarded. Investigation Four revealed a further sequence in the development of understanding: conservation of number-before-substance & length-before-weight-before-volume & area. This more extensive sequence differed from those found by other investigators. Piaget found that conservation of number develops at about 6 to 7 years of age, substance, length, and area at about 7 to 8, weight at about 9 to 10, and volume at about 11 to 12. Other investigators found different orders in the development of conservation, see for example Goldschmid (1967) and Fogelman (1970) who cites several other investigations. The particulars of the problem situations and questions presented by the different investigators very probably determined the different orders in which conservation was recognised in the extensive range of attribute situations. The sequence conservation of substance-before-weight-before-volume, however, was found repeatedly.

Why there should be this substance-before-weight-before-volume sequence is not easy to answer. Some possible explanations for the sequence found in Investigation Four were discussed there and need not be repeated here except in general terms in relation to conservation of substance, weight, and volume. Conservation of the earlier attributes may not be integral to conservation of the later; conservation of an attribute later in the sequence can be successfully taught to children who lack conservation of attributes earlier in the sequence, though conservation of the earlier attributes usually also develops. Relative complexity and familiarity of the problem situations and questions may explain the order of development of understanding of conservation. Children are likely to consider global quantity, substance, before its more abstract aspects, weight and volume. Questions about overall 'amount', substance, are relatively simple and familiar; questions about 'weight' are less so but weight is still quite directly experienced. Questions about volume are more complex. The terms 'room' and 'space' are ambiguous and may suggest that shape is relevant; volume is not easily measured or demonstrated and it is probably a less familiar consideration for children.

Question 5: In what ways is a child's recognition of conservation or continuing equality influenced by the particulars of the situation facing him? The particular presentation of conservation problems was found to influence children's recognition in two main ways: (1) when different materials were used conceptual recognition of conservation was sometimes evidenced in one but not another number, substance, area or volume situation and (2) when different transformations were made perceptual recognition of continuing equality was likewise evidenced in some but not other length or area situations.

The influence of situational differences was evident in Investigations Two, Three and Four; Investigations Two and Three revealed the importance of task specifics in the case of volume conservation particularly, and Investigation Four revealed their influence in the case of area particularly. In the case of volume, while there was no evidence of a necessary interior-before-displacement volume conservation sequence, different displacement volume situations gave rise to differences in conceptual recognition of conservation. These have been discussed in Investigations Two, Three and Four and need not be taken up again here. In the case of area, differences in the problem situations gave rise to perceptual recognition of continuing equality in some but not other situations as well as to differences in conceptual recognition of conservation, but there was no evidence of a necessary interior-before-complementary area conservation order. These findings too have been discussed at length in Investigation Four and need not be taken up here.

In addition to revealing the influence of task specifics on children's responses in volume and area conservation situations, the investigations disclosed differences in conceptual recognition of conservation of number and substance due to differences in the particular situations presented. Conservation of number was sometimes recognised in correspondence situations before it was in beads in containers situations and conservation of substance in liquid before solid substance situations.

Investigation Four revealed that perceptual recognition of continuing equality may be possible in some length as in area situations. This too has been discussed previously. Closer study of the effect of task specifics on responses in length conservation situations might clarify the findings in Investigation Four. Further study might also clarify the finding in the distance conservation situation of Investigation Four. There, all the children tested recognised the continuing equality of the distance between the objects. In the case of weight, situational differences did not give rise to any differences in recognition of conservation or continuing equality.

Finally, the finding that task specifics have an important influence on children's responses in conservation situations emphasises the importance of describing and considering in detail actual transformations made and materials used in attribute situations and also exact criteria for conceptual and perceptual judgments.

Question 6: How is a child's response to teaching influenced by his initial level of understanding? Investigations Three, Four & Five indicated that the teaching procedure and the child's initial level of understanding interact in determining whether and how far understanding of conservation develops. When in Investigation Three teaching procedures were systematically reduced, children who had less initial understanding developed less in understanding conservation. In Investigation Four, four children who initially failed to recognise conservation of number as well as five other attributes did not develop understanding of conservation with the teaching given. In Investigation Five, however, given fuller different teaching three of these four children did develop a generalised and durable understanding of conservation. Thus, a child's response to teaching was found to be influenced by an interaction between his initial level of understanding and the fullness of the instruction given to him.

Inhelder & Sinclair, in Mussen et al (1969), report Genevan learning experiments and the finding that the effectiveness of teaching varies significantly with the initial developmental level of the child. They found that the lower the child's initial level the more any progress tends to be limited to a particular problem or field. In the present research this was only found to be true when reduced teaching procedures were used; given fuller teaching children with the lower levels of initial understanding also developed the widely generalised understanding of conservation. On the basis of their experimental results, Inhelder & Sinclair drew the "tentative" conclusion that conservation of number is a prerequisite of success in learning experiments. Investigation Five of the present research provided evidence contrary to this conclusion. Three children who did not initially recognise conservation of number were successfully taught conservation. The question of prerequisite understanding, however, needs further study. Conservation of number perhaps is not a minimum essential, but undoubtedly there is some minimal degree of understanding or ability that is necessary before conservation can be successfully taught and this minimum remains to be specified.

In addition to answering the six central questions, the research has implications for the education of mentally retarded children and for understanding mental growth in general. The investigations have shown means of remedying as well as diagnosing lack of understanding of conservation in ESN children. As nonconservation is prevalent among ESN schoolchildren of all ages and as such children are less likely than normal children to 'spontaneously' develop understanding of conservation, it can reasonably be argued that special instruction on conservation is important to meet these children's everyday needs. The investigations have also revealed something of the ways in which mental development in general may occur as well as some conditions for the development of understanding of conservation in particular.

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