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An investigation of the development of conservation and transitivity in children.

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AN INVESTIGATION OF THE DEVELOPMENT OF CONSERVATION AND TRANSITIVITY IN CHILDREN

by

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ABSTRACT

This study was an investigation of the development in children, of conservation and transitivity of the properties of mass, weight and volume. Conservation refers to the ability to conceive the properties of an object as unvarying despite the object's deformation. Transitivity refers to the ability to deduce a relation between two objects from their several associations with a third object. On the basis of published literature, the simultaneous development of the concepts of conservation and transitivity and the hierarchical development of mass, before weight, before volume, for both concepts were hypothesized. It was further predicted that females would develop the two concepts of conservation and transitivity earlier than males.

Four groups of 20 subjects (10 males and 10 females), from grades 2, 4, 6 and 8 were selected from a separate school on the basis of average school achievement. The subjects were individually tested in two sessions on systematically varied tasks of conservation and transitivity. The conservation task involved the comparison of a round plasticine ball with a distorted ball with respect to its properties of mass, weight and volume. The transitivity task involved the comparison of equal relations (of round

and distorted plasticine balls A, B and C) : A = B, B = C then A = C ; followed by the inclusion of a putty (P) ball : B = P then A = P.

The results indicated that conservation developed earlier than transitivity. Although the volume property was found to develop last, the mass before weight relationship was not always found. Conservation was found to develop earlier in females at the grade two level and not at grades 4, 6 or 8. Sexes did not differ on the transitivity concept and the combined effect of the two concepts, although males were more proficient than females in grade eight.

PREFACE

This study originated from an interest in the theories of Jean Piaget, and was inspired by a seminar course in Developmental Psychology, conducted by Dr. B. Rourke.

The author wishes to express his appreciation to Dr. Miriam Bunt, under whose direction this investigation was conducted, and whose constructive criticisms and patient guidance was so helpful ; to Drs. V. B. Cervin and C. Drouillard who read the manuscript.

He also expresses his gratitude to Brother Dennis, the Principal of St. Gabriel's Separate School, and to all the children who were so cooperative as subjects. Finally, he would like to express his appreciation to Mr. H. Ladd and Mr. X. Plause who assisted in the capacity of judges, and were helpful with the statistical procedures applied to the study.

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CHAPTER I

Introduction

Theoretical Considerations

This study is an investigation of the development in children, of the intellectual operations of conservation and transitivity of mass, weight and volume. The ability to "conserve" refers to an awareness that material will not vary in these basic attributes despite any apparent deformation. Transitivity refers to the ability to deduce a relation between two objects from their several associations with a third object.

It has been suggested (Flavell, 1963), that cognitive activity is grounded on a foundation of complex operations which are reversible and internalized. These operations become evident in the concrete level of cognitive development when the gradual coordination of relations forms a "mobile equilibrium", that is to say when "they acquire the character of reversibility (of being able to return to their original state or starting - point)" (May, 1957, p.13). The most elementary operational structures appearing at the concrete level of cognitive development can be conceptualized as "logical groupements" or groupings i.e. imperfect groups of classes and relations (Piaget, 1949). For example, children learn at about the age of six or seven that parts or subclasses may be included in a "whole" without knowing the magnitude of these parts in relation to the whole (i.e. A + A' = B).

The grouping which represents cognitive conservation is the "biunivocal multiplication of relations", or grouping number seven. This grouping involves a one - to - one coordination, i.e., multiplication of two (or more) series of relations, and conceptualizes "virtually all conservation studies i.e. those in which some kind of equality (of quantity, of length, of area, etc) between two objects A and A' is "conserved" or kept unchanged in the face of some transformation" (Flavell, 1963, p. 195). The grouping which represents transitivity is the "addition of asymmetrical relations", or grouping number five. Its basic operation is seriation along one dimension, or the arrangement of elements into a "transitive, asymmetrical series" (i.e. A is larger than B, B is larger than C etc). This grouping is fundamental to the transitivity of equivalence relations i.e. to "the construction of equivalences which correspond to the first stage of the evolution of seriation" (Piaget and Inhelder, 1941, p. 251), and which logically are a special case of asymmetrical relations.

In this early work (Piaget and Inhelder, 1941), the concepts of conservation and transitivity were investigated with regard to the properties of mass, weight and volume of physical quantities. Piaget concluded that the conservation of the property of mass developed before that of weight, which developed before that of volume. He found that there was a three stage process in the development of each concept. The first stage was that of non conservation and non transitivity. With respect to conservation, the child centred either on the length or the width etc. of the object, and was unable to coordinate the two. With respect to transitivity, he could equate two immediately perceived objects (A = B or B = C), but could not perform the relationship between three objects (A = B, B = C then A = C). During the second stage, the child expressed an intermediary reaction between conservation (and transitivity) and non conservation (and non transitivity) at which time he could arrive at the correct solution by centering on the qualitative or physical characteristics of the object. In the conservation task the child could coordinate two aspects of the whole, the length and the width, but could affirm invariance merely by empirical presumption. In the transitivity task, although the child could establish the A = C relationship when A = B and B = C, the result was based upon the apparent quantity of matter. During the third stage the child would admit of conservation and transitivity by logical necessity.

A typical procedure used by Piaget (Piaget and Inhelder, 1941) to investigate the development of conservation of weight was as follows. There were two balls of clay of equal size, shape and weight, yet different in colour. One was elongated into a sausage, and a child was asked if the sausage weighed the same as the other ball of clay. He found that in the development of the conservation of weight, children proceeded through three steps : non conservation due to perceptual dominance, an intermediary stage, and conservation by logical necessity.

The procedure to investigate transitivity involved four rectangular bars of brass (A, B, C, D), which were differently coloured yet equal in size and weight : and a bar of lead (X) which although different in substance and size, was equal in weight to the other four bars. He used a balance to show the child that A = B and B = C in weight ; then he asked if C was equal in weight to A, and why. He then weighed B and X (B = X), and asked if X was equal in weight to A, and why. He found that the youngest child could not compose the relationship A = B, B = C, then A = C, when the brass bars were of different colours. Older children, performing at the intermediary stage, could compose this relationship even when coloured brass bars (of homogeneous substance) were used. It was not until nine or ten years of age that the children could compose the transitive relationship

A = B, B = C, A = C and B = X then A = X with equal weights of a different density. The culmination of this third stage revealed the child's ability to logically compose the weight relationship when it was not proportional to the apparent quantity of matter.

Piaget's investigation of these two concepts revealed that the development of the properties of mass, weight and volume followed a regular order that was related to age. The property of mass was discovered at ages seven to eight; the property of weight was discovered at ages nine to ten; the property of volume was discovered at ages eleven to twelve. He further concluded that "logico - arithmetical operations" (reflected in transitivity) and "physical operations" (reflected in conservation) interacted, and "there was nothing surprising in that the development of physical operations were synchronous with logico - arithmetical operations ; with the same stages and with the same temporal displacement" (Piaget and Inhelder, 1941, p. 277).

Related Studies

There have been an increasing number of validation studies pertaining to Piaget's work on the development of quantity concepts. Elkind (1961b) administered Piaget's conservation tasks to 175 children from kindergarden through grade six. His results corroborated Piaget's in that the mean age of attainment of the relative properties implied a sequential order of mass, before weight, before volume. Although Piaget assumed no statistical criterion in his conservation experiments, in some of his other studies (1959), he indicated a criterion of 75 per cent as a "passing point". Retaining this figure as a criterion for his investigation, Elkind found that the 75 per cent level, with respect to correct answers on the volume concept, was not reached at the eleven age level. An additional investigation (Elkind, 1961a), with junior and senior high school students having a mean I Q of 100.4 revealed that the criterion for the volume task was not met until a mean age of 17.7. His results further indicated that females responded at the same level as males on the properties of mass and weight. However the mean percentage of successful males on the volume task was 54, while that of the girls was 40. Additional research, using children of average intelligence (Pauley, 1959 ; Ames and Ilg, 1964) indicated large sex differences, with girls at early grade levels performing significantly better than boys. Piaget (Piaget and Inhelder, 1941) reported no sex differences in his studies. Kooistra's study (1964) on conservation and transitivity also revealed no apparent sex difference in a sample of children of superior intelligence (Binet I Q of 135).

Lovell and Ogilvie (1961), supported the hypothesis that conservation of weight occurred later than conservation of mass. Their results also indicated that most children who were conservers could perform the logical operation of transitivity. This was not found to be unvarying. Many children who were not conservers could perform the operation of transitivity. They also found that seventy per cent of the 114 conservers believed that weight was associated with the hardness of the material. Piaget used a soft substance (i.e. clay) for his conservation tasks and a hard substance (i.e. brass) for his transitivity tasks. The different degrees of hardness of these two substances may have influenced his finding that there was a simultaneous development of the concepts of conservation and transitivity.

Smedslund's investigation (1961) of conservation of mass and weight, and transitivity of weight involved children with an average age of 6.2 years. His conservation tasks were similar to those of Piaget (Piaget and Inhelder, 1941). The transitivity tasks involved both symmetrical and asymmetrical relationships using rounded and distorted balls of plasticine. His results indicated that the conservation of mass and weight, and transitivity of weight occurred at earlier age levels than those proposed by Piaget. Braine (1959) found similar results with respect to the development of transitive length relationships. Although Smedslund (1961) did find conservation of mass developing earlier than that of weight, he maintained that these results could have been influenced by the transfer effect due to the immediate succession of presented tasks. His results further indicated "no appreciable correlation between the acquisition of conservation of weight and the acquisition of transitivity of weight" (p. 81). This last result would not support Piaget's investigation (Piaget and Inhelder, 1941) of the synchronous development of conservation and transitivity.

Derivation of Hypotheses

An apparent discrepancy between the procedures of Piaget and Smedslund, may have accounted for their different results. Although Smedslund employed objects differing in colour and shape, they were all of a homogeneous substance (i.e. plasticine). On the other hand, Piaget's use of the two substances enabled him to determine that stage of cognitive development at which the child could conceive of weight as being physically invariant and divorced from the quantity of the matter. If Smedslund's task were applied to Piaget's formulation, his results would be consistent with Piaget's second stage of weight transitivity, at which time the child focusses on the "composition" of the quantity of matter. "In the case of two bodies of different densities, not expressing an equality of matter, nothing will permit the child to distinguish the apparent quantities, based upon perceptive volume, from corpuscular quantities" (Piaget and Inhelder, 1941, p.182). In other words, during this second stage, the child will base his judgment on the size of the object, rather than take into account that fact that a different material may be equal in weight to the object, yet differ in size.

The present investigation will be an extension of Smedslund's. In the first place it will involve the use of materials of two densities. Second, it will consider not only the property of mass and weight, but also volume. By employing these three properties, the problem will be given a more substantial consideration. Third, the order of acquisition with respect to these three properties, in regard to conservation and transitivity will be investigated. Fourth, in order to avoid the apparent transfer effect reported by Smedslund (1961), the tasks will be randomized and administered in two sessions. Fifth, sex differences with respect to performance on the individual tasks will be investigated.

The following formal hypotheses are derived from the preceeding studies.

1. The concrete operations of conservation and transtivity develop synchronously for any given domain of application (i.e. mass, weight, volume).

2. The development of conservation and transitivity follows a regular order : mass, before weight, before volume.

3. The development of conservation and transitivity occurs earlier in females than in males.

CHAPTER II

METHODOLOGY AND PROCEDURE

Subjects

Four groups of 20 children from a Windsor Separate School served as subjects. An equal number of boys and girls were drawn from grades two, four, six and eight. The mean age in each grade was : grade two, 7.1 years; grade four, 9.1 years ; grade six, 11.0 years; grade eight, 13.3 years. Each group was selected on the basis of school achievement, with all the subjects within the medium range. All subjects were, by the principal's estimation, selected from approximately the same socioeconomic background.

Equipment

The material used in this study consisted of five balls of plasticine, all equal in size and weight but different in colour. Two balls of window putty were also used. One (P_1) was equal in weight to the balls of plasticine but smaller in size. The other (P_2) was equal in size to the other balls of plasticine, but heavier. The remainder of the equipment involved a hand balance, and a Phillips tape recorder, model 330.

Procedure

The subjects were individually tested in the nurse's office of the separate school. The subjects and experimenter were seated opposite each other with the balance and balls of plasticine and window putty placed in front of and to the left of the subject. The tape recorder was turned on after the subject entered the room, with the microphone placed to the right of subject. Each subject was tested in two sessions on two successive days. There was no reinforcement given by experimenter, either by verbal means or facial gesture. Although the procedure for each subject was randomized, the following is a typical example :

1st day : conservation of mass - transitivity of volume - conservation of weight

2nd day : transitivity of weight - conservation of volume - transitivity of mass

Test for the conservation of mass

(To facilitate the explanation the balls of plasticine will be referred to as A, B and C, and the putty balls as P_1 and P_2. Three of the five coloured plasticine balls were randomly selected for each test to avoid any perceptual cue with colour). A and B were placed before the subject who was asked if B had the same amount of plasticine in it as A : or if it had more or less. If the subject declared that A and B did not have the same amount of plasticine in them, he was encouraged to make them equal by either adding to, or removing from B, a quantity of plasticine. Then the experimenter, rolled one of the balls (B) into the shape of a sausage and asked if the sausage had more plasticine in it than the ball (A) ; or if it had the same amount, or less. The deformed shapes were systematically varied among the subjects for all tasks. After his judgment, the subject was asked in a neutral tone of voice, " why do you think so? ".

Following the deformation of B, regardless of whether the conservation R. had been given, B was reformed before the subjects eyes, into the original ball. The same question regarding the equality in substance was again asked. The procedure was then altered and the experimenter deformed the A ball into a ring and asked the subject if it had the same amount of plasticine as B, and why. This second procedure was used to determine whether the subjects reasoning was unyielding, and whether his conclusions (if he was found to conserve material) were maintained with certainty. Although both explanations (i.e. " why? ") were recorded, only if both explanations were conservative would the subject be considered as having attained conservation of mass. The two procedures are seen below :

a) A (ball of plasticine) = B (deformed into a sausage)
b) A (deformed into a ring = B (ball of plasticine)

Test for conservation of weight and volume

In testing for the conservation of weight, the subject was first given the opportunity to familiarize himself with the balance. The remaining procedure for weight and for volume was similar to that for mass, except the questions were phrased as " do they weigh the same? etc. " and " do they take up the same amount of room or space? ".

Test for transitivity of weight

The child was given the opportunity to familiarize himself with the balance, if he had not done so previously.

Three balls of plasticine (A,B,C) were selected by the experimenter, along with the putty ball, P_1. A and B were placed on the two pans of the balance, to determine their relative weight (A = B). A was then removed and replaced by B. The third ball (C) was then placed in the opposing pan (B = C). Two balls (A and C) were then placed before the subject and the experimenter asked him if C was lighter than, equal in weight to, or heavier than A, and why (A = C). The coloured ball B, and the putty ball P_1, were also placed on the balance and found to be equal. The subject was then asked if P_1 was lighter than, equal in weight to, or heavier than A ($A = P_1$). This was followed by the explanation of his answer. This procedure was later repeated with A, B and C deformed into such shapes as rings, sausages and plates. As with the conservation tasks, these shapes were systematically varied among the subjects in the transitivity tasks. Both round and deformed lumps of plasticine were used in order to overcome a perceptual centering on shape (i.e. roundness), and to approximate as close as possible Smedslund's technique (1961). The following is a typical example of the procedure used :

a)

A (red ball)	=	B (blue ball)
B (blue ball)	=	C (green ball)
A (red ball)	=	C (green ball)
B (blue ball)	=	P_1(putty ball)
A (red ball)	=	P_1(putty ball)

b)

A (ring)	=	B (block)
B (block)	=	C (plate)
A (ring)	=	C (plate)
B (block)	=	P_1(putty ball)
A (ring)	=	P_1(putty ball)

By using both the plasticine and putty, the experimenter attempted to overcome those responses which are elicited because of the composition of the material. Only correct A = P responses, and explanations on both of tasks (a) and (b) were considered as adequate indications of the attainment of transitivity of weight.

Transitivity of mass and volume

The same procedure was followed as with transitivity of weight, except the subjects were asked if the two substances (i.e. plasticine and putty) had the same amount of material, and if they took up the same amount of room or space. In these two tests, the putty ball P_2 was used in place of P_1.

Scoring System

Smedslund's (1961) scoring system was used as a model for this investigation. His study involved not only correct and incorrect responses, but also the type of explanation given. To make the scoring system as objective as possible Smedslund's two categories of correct and incorrect explanations were used. A correct response and explanation on both (a) and (b) of each of the conservation and transitivity tasks was scored as "one". An incorrect response on either (a) or (b) resulted in a score of "zero". An interscorer reliability check was performed on the raw data (Appendix A) by two pre-doctoral candidates. The categories of the scoring system were as follows :

Correct Explanations

Symbolic : are responses which refer to explanations relating back to the previous events of the task.
In conservation : i.e. " they weighed the same when they were balls " or " you can reshape them into the original shape " (size etc).

In transitivity : i.e. " this last one is the same as the second ".

Symbolic logical : In conservation : refers to explanations implying that nothing has been added or taken away from the original (i.e. " It has to be the same, always " or " It cannot become more ").

In transitivity : refers to explanations which relate to the two previous premisses of the task (i.e. A = C because A = B and B = C).

Incorrect Explanations

Perceptual : refers to explanations concerning the observable events of the situation (i.e. " it just looks the same ").

Ambiguous : refers to any explanations which cannot be subsumed under the other three categories, or have no bearing on the problem (i.e. " they may have been the same when you bought them ").

CHAPTER III

RESULTS

A summary of the correct number of responses with respect to grade, sex, concept (conservation and transitivity), and properties of concept (mass, weight and volume), is given in Table 1. Totals for the correct number of responses, over the four grade levels, for males and females, are also presented in this table for the concepts of conservation and transitivity. The raw scores for the data in Table 1 are given in Appendix A.

A random selection of four subjects, two female and two male, over the four grade levels, were subjected to an interscorer reliability check on the basis of their responses. The percentage of agreement between the two judges and the experimenter was 97.8, on a total of 96 responses.(Appendix B).

The results are presented in three sections : the correct number of responses for (1) the three properties of the conservation concept, (2) the three properties of the transitivity concept, (3) the combination of the conservation and transitivity concepts.

Table 1

Correct Number of Responses in Conservation and Transitivity Tasks

		Conservation					Transitivity				N. = 80
		Mass	Weight	Volume	Total Between Sexes	Total Between Grades	Mass	Weight	Volume	Total Between Sexes	Total Between Grades
Grade Two	Females	5	3	2	10	12	0	1	0	1	3
	Males	1	1	0	2		1	1	0	2	
Grade Four	Females	6	7	2	15	30	3	3	0	6	15
	Males	7	7	1	15		4	4	1	9	
Grade Six	Females	9	8	2	19	38	3	2	0	7	12
	Males	10	9	0	19		3	2	0	5	
Grade Eight	Females	8	9	1	18	40	1	2	0	3	18
	Males	9	8	5	22		4	6	5	15	
					Total	120				Total	48

Conservation Tasks

Table 1 indicates the total number of correct responses over the four grade levels. A trend analysis of these totals shows a linear ($F = 30.66$) and a quadratic relationship ($F = 4.64$), both significant at the .01 level. A comparison of the total number of correct responses for grade levels indicates a difference ($F = 11.61$) significant at the .01 level, between grades two and four, and no difference between grades four and six, and six and eight. Inspection of Table 1, indicates that in grade four, approximately 70 per cent of the males and females have developed the conservation of mass and weight.

The three properties of conservation (mass, weight, and volume) were measured over grades 2, 4, 6 and 8 for both females and males. An analysis of variance on the conservation data contained in Table 1 was performed. The results of this analysis showed a significant difference with respect to the four grades, at the .01 level. The significance at the .01 level of the effect of the three properties of conservation, indicates that the procedure employed has successfully differentiated these properties with respect to difficulty. The significant interaction of grade by properties of conservation indicates that the grade levels have a differential effect upon the acquisition of the three properties of conservation. These results are shown in Table 2.

Table 2

Analysis of Variance for Conservation

Source of Variance	df	MS	F ratio
Between Subjects	79		
A (grade)	3	2.71	11.78*
B (sex)	1	.01	
AB (grade x sex)	3	.43	1.86
Error between	72	.23	
Within Subjects	160		
C (property)	2	6.86	62.36*
AC (grade x property)	6	.51	4.64*
BC (sex x property)	2	.01	
ABC (grade x sex x property)	6	.19	1.72
Error within	144	.11	

* $F_{.99}(3,72) = 4.11$ * $F_{.99}(2,144) = 4.78$

* $F_{.99}(6,144) = 2.95$

Because of the significant main and interaction effects, an analysis of simple effects was calculated to determine the regions of the individual sources of variation (Table 3). The variation for grade levels is found significant, at the .01 level, for both sexes, for the properties of mass and weight, but not for volume. The variation due to the effect of properties is significant for grades 4, 6 and 8, but not for grade two (Table 3). Inspection of Table 1, for conservation indicates that the

Table 3

Analysis of Simple Effects for Conservation

Source of Variance	df	MS	F ratio
Grade for Females	3	.55	2.39 ***
Males	3	2.59	11.26 *
Error	72	.23	
Grade for Mass	3	1.65	11.00 *
Weight	3	1.90	12.67 *
Volume	3	.18	1.20
Error	72	.15	
Sex for Grade 2	1	1.07	7.13 *
Grade 4	1	.00	.00
Grade 6	1	.01	.07
Grade 8	1	.26	1.73
Error	72	.23	
Property for Grade 2	2	.20	1.82
Grade 4	2	1.85	16.68 *
Grade 6	2	4.32	39.27 *
Grade 8	2	2.01	18.27 *
Error	144	.11	
Property for Females	2	3.51	31.91 *
Males	2	3.36	30.55 *
Error	144	.11	

*$F_{.99}(3,72) = 4.11$ *$F_{.99}(2,144) = 4.78$

*$F_{.99}(1,72) = 7.06$ *$F_{.99}(6,144) = 2.95$

***$F_{.90}(3,72) = 2.17$

variation due to grades 4, 6 and 8 is attributed to the correct number of responses between volume, and the combined effect of mass and weight. The lack of significance in grade two suggests no difference in the development of the three properties at this grade level.

Inspection of Table 3 and Figure 1 indicates that the significant source of variation attributed to sex differences in grade two is due to the significantly better performance of females at this level. The variation due to sex differences is not significant for grades 4, 6 and 8.

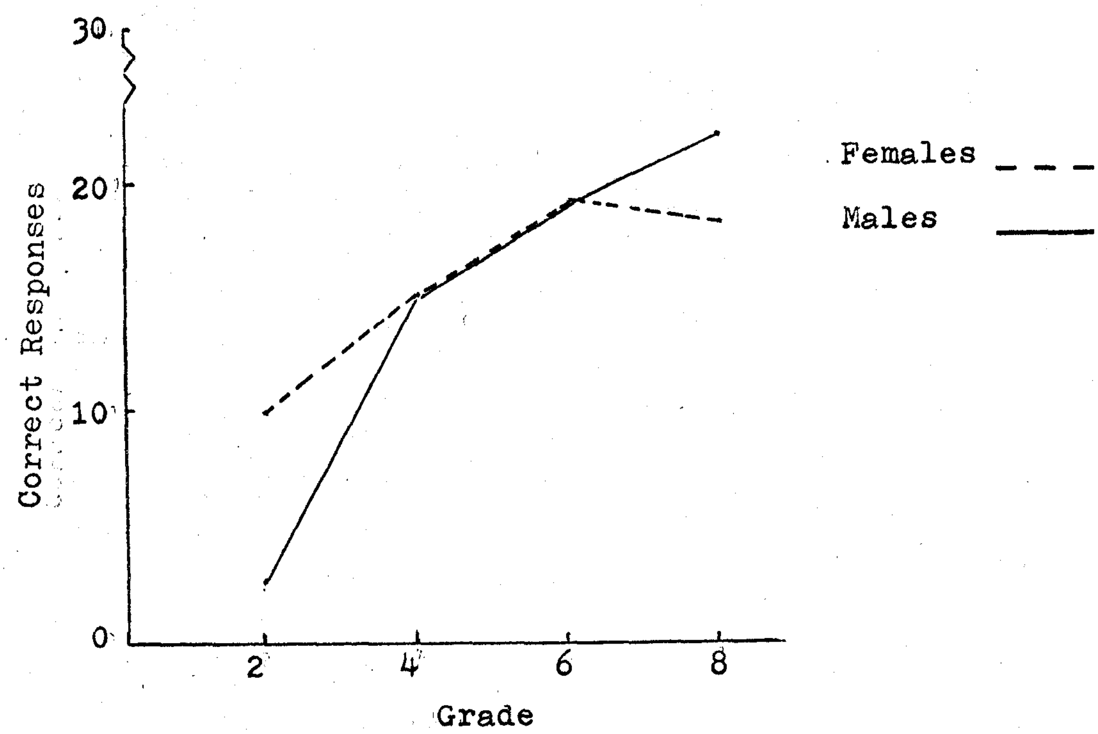

Figure 1 : Profile of simple effects of sex for level of grade in conservation.

Transitivity Task

An analysis of variance for the transitivity data contained in Table 1 was performed over the four grade levels for both males and females. The results of this analysis are given in Table 4. The source of variation for the grade levels significant at the .01 level indicates that an increase in the correct number of responses is a function of grade level. Table 1 illustrates the total number of correct responses for the transitivity task from which a trend analysis was computed. The results of this analysis indicated a linear trend ($F = 6.125$) significant at the .01 level. A comparison of the correct number of responses for grade levels indicated a difference significant at the .01 level ($F = 5.00$) between grades two and four, and no difference between grades four and six, and six and eight. A significant property effect (mass, weight and volume) suggested that the number of correct responses was a function of the difference between the level of acquisition of these properties.

The results were further analyzed by simple effects as shown in Table 5. The analysis indicated a significant degree of variation over grade levels for males but not for females. This variation was found significant for grade eight, but not for grades 2, 4 and 6.

Table 4

Analysis of Variance for Transitivity

Source of Variance	df	MS	F ratio
Between Subjects	79		
A (grade)	3	.70	2.92**
B (sex)	1	.82	3.42***
AB (grade x sex)	3	.60	2.50***
Error between	72	.24	
Within Subjects	160		
C (property)	2	.98	10.89*
AC(grade x property)	6	.14	1.55
BC(sex x property)	2	.03	.33
ABC(grade x sex x property)	6	.03	.33
Error within	144	.09	

** $F_{.95}(3,72) = 2.74$ * $F_{.99}(2,144) = 4.78$

*** $F_{.90}(3,72) = 2.17$ *** $F_{.90}(1,72) = 2.78$

Table 5

Analysis of Variance for Simple Effects for Transitivity

Source of Variance	df	MS	F ratio
Grade for Females	3	.25	1.04
Males	3	1.05	4.37*
Error	72	.24	
Sex for Grade 2	1	.01	00
Grade 4	1	.15	.06
Grade 6	1	.07	.03
Grade 8	1	2.40	10.00*
Error	72	.24	
Sex for Mass	1	.31	2.21
Weight	1	.12	.09
Volume	1	.45	3.21***
Error	72	.14	
Property for Grade 2	2	.05	.06
Grade 4	2	.60	6.67*
Grade 6	2	.60	6.67*
Grade 8	2	.15	1.67
Error	144	.09	
Property for Females	2	.65	7.22*
Males	2	.36	4.00**
Error	144	.09	

* $F_{.99}(3,72) = 4.11$ *$F_{.99}(1,72) = 7.06$

* $F_{.99}(2,144) = 4.78$ **$F_{.95}(2,144) = 3.05$

***$F_{.90}(1,72) = 2.79$

Inspection of Table 1 and the profile of simple effects (Figure 2) indicates that males perform significantly better than females in grade eight. Much of this difference is attributed to the significantly better performance by males on the volume property.

The variation in grade levels due to the properties of mass, weight and volume in transitivity is significant in grades four and six, but not in grades two and eight. This suggests some difference in the level of attainment of the three properties in grades four and six.

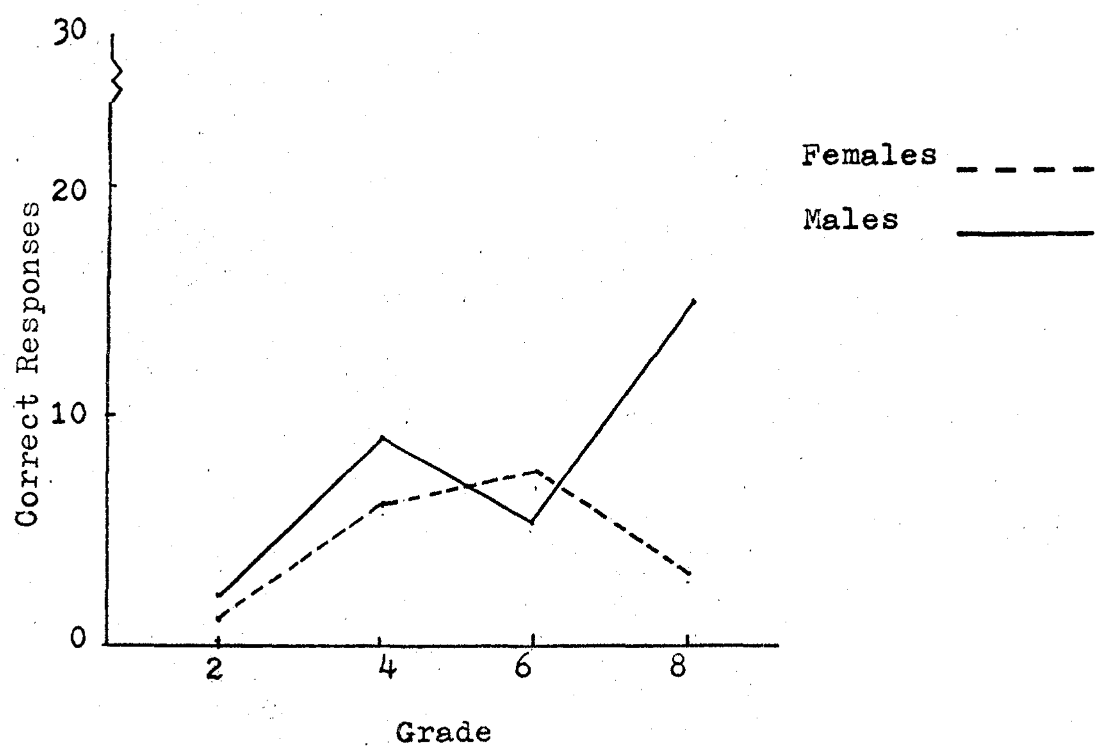

Figure 2 : Profile of simple effects for grade by sex interaction in transitivity.

Conservation and Transitivity

Since the same people were subjected to the tasks involving the concepts of conservation and transitivity, a four way analysis of variance was computed for grade, sex, concepts (conservation and transitivity) and properties (mass, weight and volume). The analysis was performed to determine if there were any significant differences between the acquisition of the two concepts and the interactions of sex and grade. The results of the analysis, based on all of the data in Table 1, are given in Table 6.

The significant grade by sex interaction indicated that the variation due to the correct number of responses over the four grade levels, was a function of the sex differences. This suggested a need for a further analysis of simple effects to determine at what grade level this variation occurred (Table 7). As indicated in Table 7 this variation occurred in grade eight with respect to the males. This variation was a function of both concepts. Figure 3 illustrates the profile of this interaction based on the number of correct responses. An F ratio of 6.47 significant at the .01 level, indicates that at the grade eight level, males perform better than females. Although the difference is not significant at the grade two level, the profile suggests that males are performing at a lower level than females.

Table 6

Results of a Four-Way Analysis of
Variance for Conservation and Transitivity

Source of Variance	df	MS	F
Between Subjects	79		
A (Grade)	3	2.939	88.88 *
B (Sex)	1	.208	.06
AB (Grade x Sex)	3	.814	2.47 ***
Error Between	72	.330	
Within Subjects	400		
C (Concept)	1	10.800	74.483 *
AC (Grade x Concept)	3	.472	3.25 **
BC (Sex x Concept)	1	.675	4.66 **
ABC (Grade x Sex x Concept)	3	.214	1.48
C x Ss within Groups	72	.145	
D (Property)	2	6.419	59.44 *
AD (Grade x Property)	6	.482	4.46 *
BD (Sex x Property)	2	.027	.25
ABD (Grade x Sex x Property)	6	.108	1.00
D x Ss within Groups	144	.108	
CD (Concept x Property)	2	1.431	15.39 *
ACD (Grade x Concept x Property)	6	.162	1.74
BCD (Sex x Concept x Property)	2	.006	.07
ABCD (Grade x Sex x Concept x Property)	6	.120	1.29
CD x Ss within Groups	144	.093	

$*F_{.99}(3,72) = 4.11$ $***F_{.90}(3,72) = 2.17$ $*F_{.99}(1,72) = 7.06$

$*F_{.99}(2,144) = 4.78$ $*F_{.99}(6,144) = 2.95$ $**F_{.95}(3,72) = 2.75$

$**F_{.95}(1,72) = 3.99$

Table 7

Analysis for Simple Effects
on Conservation and Transitivity

Source of Variance	df	MS	F
A For Females	3	.661	2.00
Males	3	3.093	9.37*
Error	72	.330	
A For Conservation	3	1.711	7.22 *
Transitivity	3	.700	2.95 **
Error	72	.237	
A For Mass	3	1.575	8.65 *
Weight	3	1.873	10.29 *
Volume	3	.458	2.51 ***
Error	72	.182	
B For Grade 2	1	.408	1.23
Grade 4	1	.075	.23
Grade 6	1	.034	.10
Grade 8	1	2.134	6.47 *
Error	72	.330	
B For Conservation	1	.023	.10
Transitivity	1	.827	3.45 ***
Error	72	.237	
C For Grade 2	1	.675	4.65 **
Grade 4	1	1.875	12.93 *
Grade 6	1	5.634	38.86 *
Grade 8	1	4.034	27.82 *
Error	72	.145	
C For Females	1	8.417	58.05 *
Males	1	3.038	20.95 *
Error	72	.145	
C For Mass	1	8.100	67.50 *
Weight	1	5.256	43.80 *
Volume	1	.306	2.55 ***
Error	72	.120	

continued

Source of Variance	df	MS	F
D For Grade 2	2	.175	1.62
Grade 4	2	2.450	22.68*
Grade 6	2	4.058	37.57*
Grade 8	2	1.358	12.57*
Error	144	.108	
D For Females	2	3.519	32.58*
Males	2	2.929	27.12*
Error	144	.108	
D For Conservation	2	6.862	54.46*
Transitivity	2	14.631	115.12*
Error	144	.126	
AB For Conservation	3	5.022	21.19*
Transitivity	3	1.555	6.56*
Error	72	.237	
AC For Females	3	.144	.99
Males	3	.548	3.78**
Error	72	.145	
CD For Females	2	.660	3.13**
Males	2	.787	3.73**
Error	144	.211	

***$F_{.90}(1,72) = 2.74$ ***$F_{.90}(3,72) = 2.17$ **$F_{.95}(1,72) = 3.98$

*$F_{.99}(3,72) = 4.11$ *$F_{.99}(1,72) = 7.06$ *$F_{.99}(2,144) = 4.78$

**$F_{.95}(3,72) = 2.75$ **$F_{.95}(2,144) = 3.13$

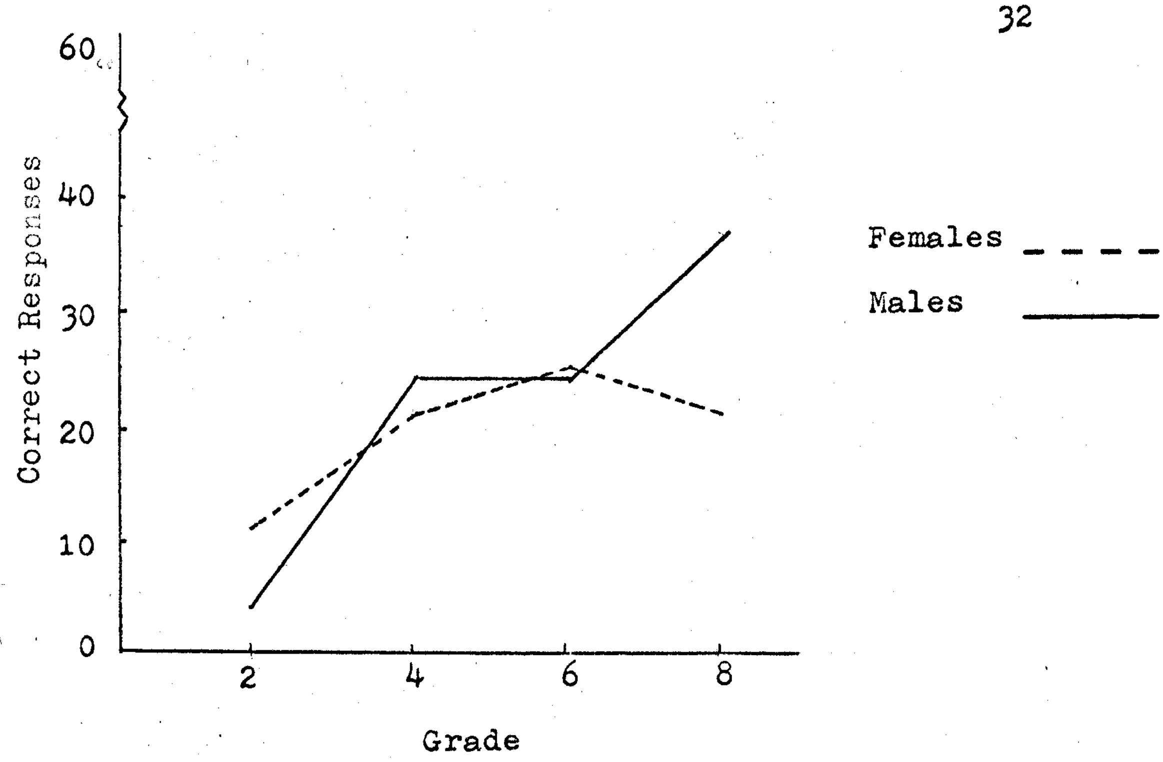

Figure 3 : Profile of simple effects for grade by sex interaction

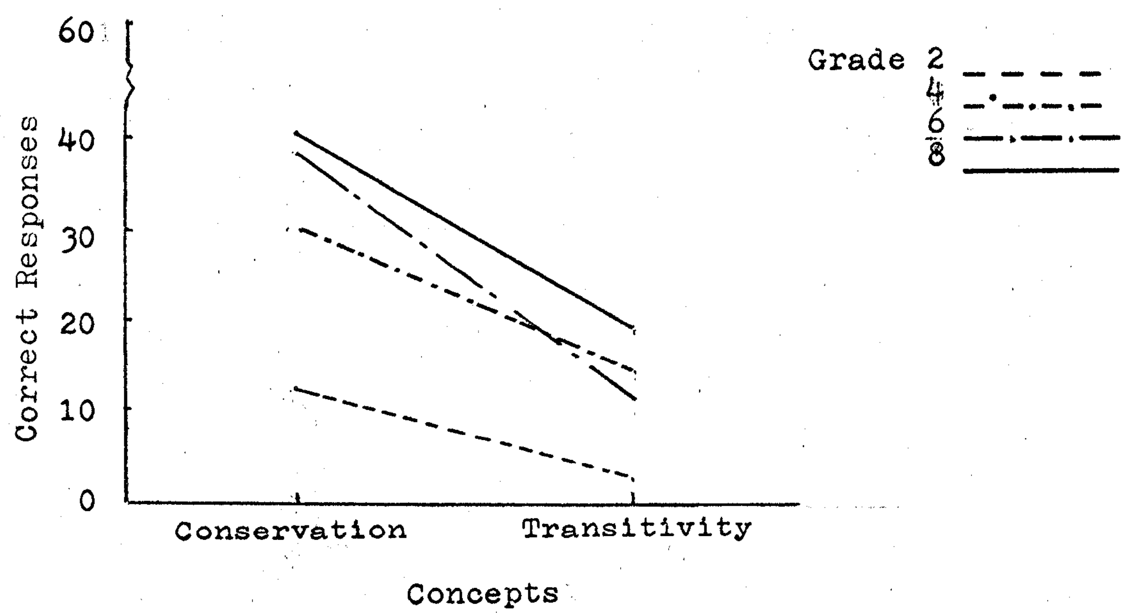

Figure 4 : Profile of simple effects for grade by concept interaction

The significant grade by concept interaction (Table 6) indicates that the number of correct responses for the two concepts varies over the four grade levels. Inspection of Table 7 indicates a significant difference over all grade levels for both concepts. However, the simple interaction effect, significant at the .01 level, indicates that this difference is due to the significant source of variation in males. This interaction is illustrated by profile 4. Inspection of this profile indicates that at all grade levels the concept of transitivity is attained later than conservation. Additional F ratio's computed on the conservation tasks between different grade levels indicates a difference, significant at the .01 level ($F = 11.35$), between grades two and four. The lack of significance between grades four and six, and six and eight indicates that there is no increase between grades four and eight, in the capacity to use the conservation concept. An F ratio of 5.04, significant at the .01 level, between grades two and four on the transitivity concept, and the lack of significance between grades four and six, and six and eight, indicates that there is no increase between grades four and eight, in the capacity to use the transitivity concept.

Since the grade by property interaction was significant at the .01 level, a profile was drawn to illustrate the simple effects (Figure 5). Inspection of the profile indicates that the variation due to the difference between the two concepts at all grade levels is attributed to the variation for the two properties of mass and weight between grades two and four and for the property of volume between grades six and eight. The lack of significance for the property of volume between grades two and four, and four and six, indicates that there is no difference over the three grade levels in the lack of capacity to use the volume property. An F ratio significant at the .01 level (F = 5.56), between grades six and eight, suggests an increase in the development of the property of volume between grades six and eight. Inspection of Table 1 indicates that the combined number of correct volume responses for conservation and transitivity at grades six and eight are two and eleven respectively.

The sex by concept interaction is illustrated in Figure 6. This shows the interaction between males and females on the concepts of conservation and transitivity. Individual F ratios, significant at the .01 level, indicate that conservation develops earlier than transitivity in both males and females. An F ratio of 3.45, significant at the .05 level, indicates that males perform better than females on the transitivity concept. There is no significant difference between sexes on the conservation concept.

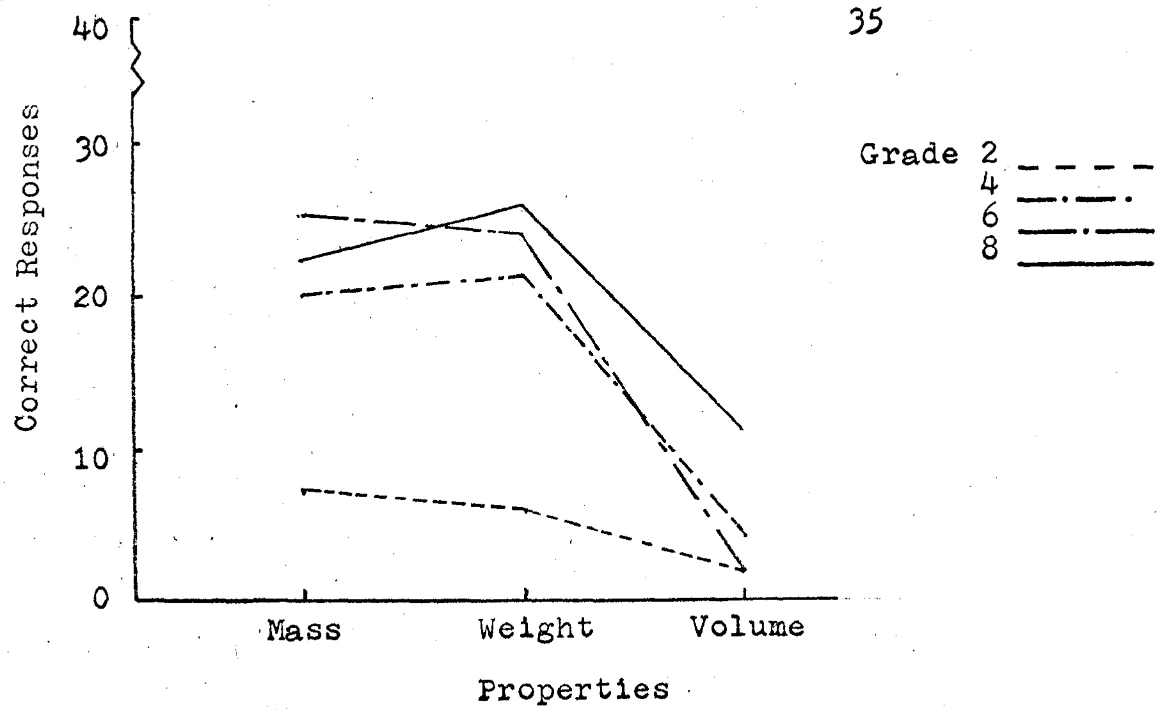

Figure 5 : Profile of simple effects for grade by property interaction.

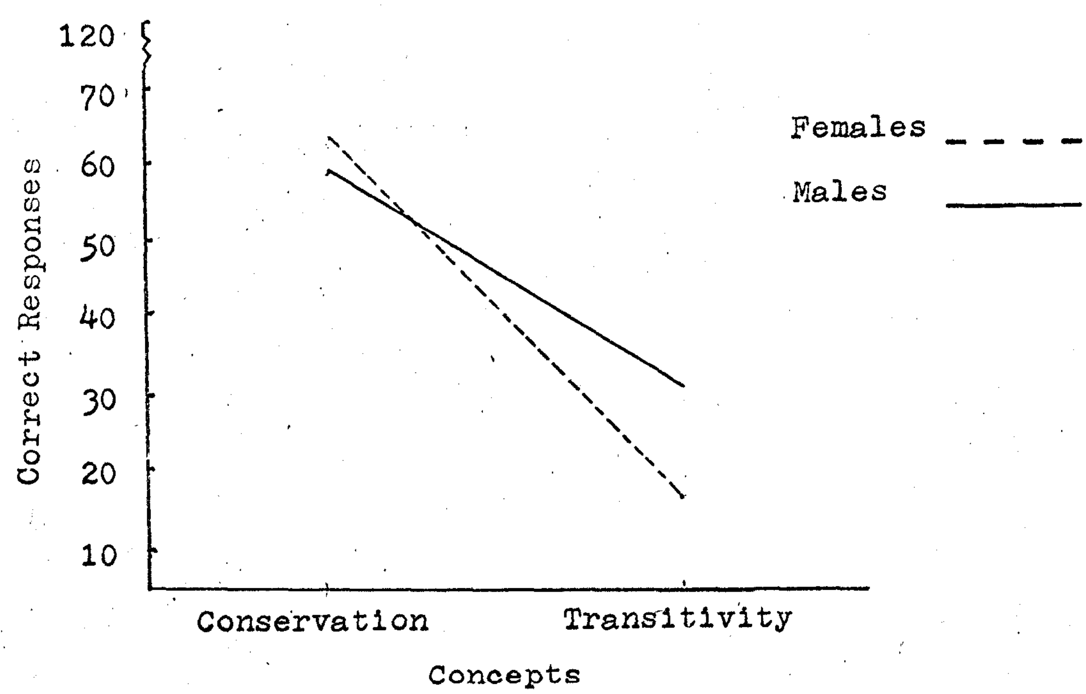

Figure 6 : Profile of simple effects for sex by concept interaction.

Inspection of Table 7 indicates a significant difference between the concepts of conservation and transitivity for the properties of mass, weight and volume. This significant concept by property interaction is shown in a profile of simple effects in Figure 7. Significant F ratios, for both conservation and transitivity indicate a difference, significant at the .01 level, between weight and volume. There is no significant difference between mass and weight. Individual F ratios for all properties indicate that the three properties of mass, weight and volume in conservation differ significantly from the three properties in transitivity (Table 7). Inspection of Figure 7 suggests that conservation of the three properties develops earlier than transitivity, and conservation and transitivity of the properties of mass and weight develop in parallel.

Additional Analysis

Figure 4 indicated that at all grade levels conservation developed earlier than transitivity. The correct responses on the transitivity tasks were based on the correct solutions involved in the use of materials of two densities (i.e. plasticine and putty). Since this result did not confirm the hypothesis, the calculation of the correct responses based on only the plasticine (A = B, B = C then A = C) was suggested to me. The raw

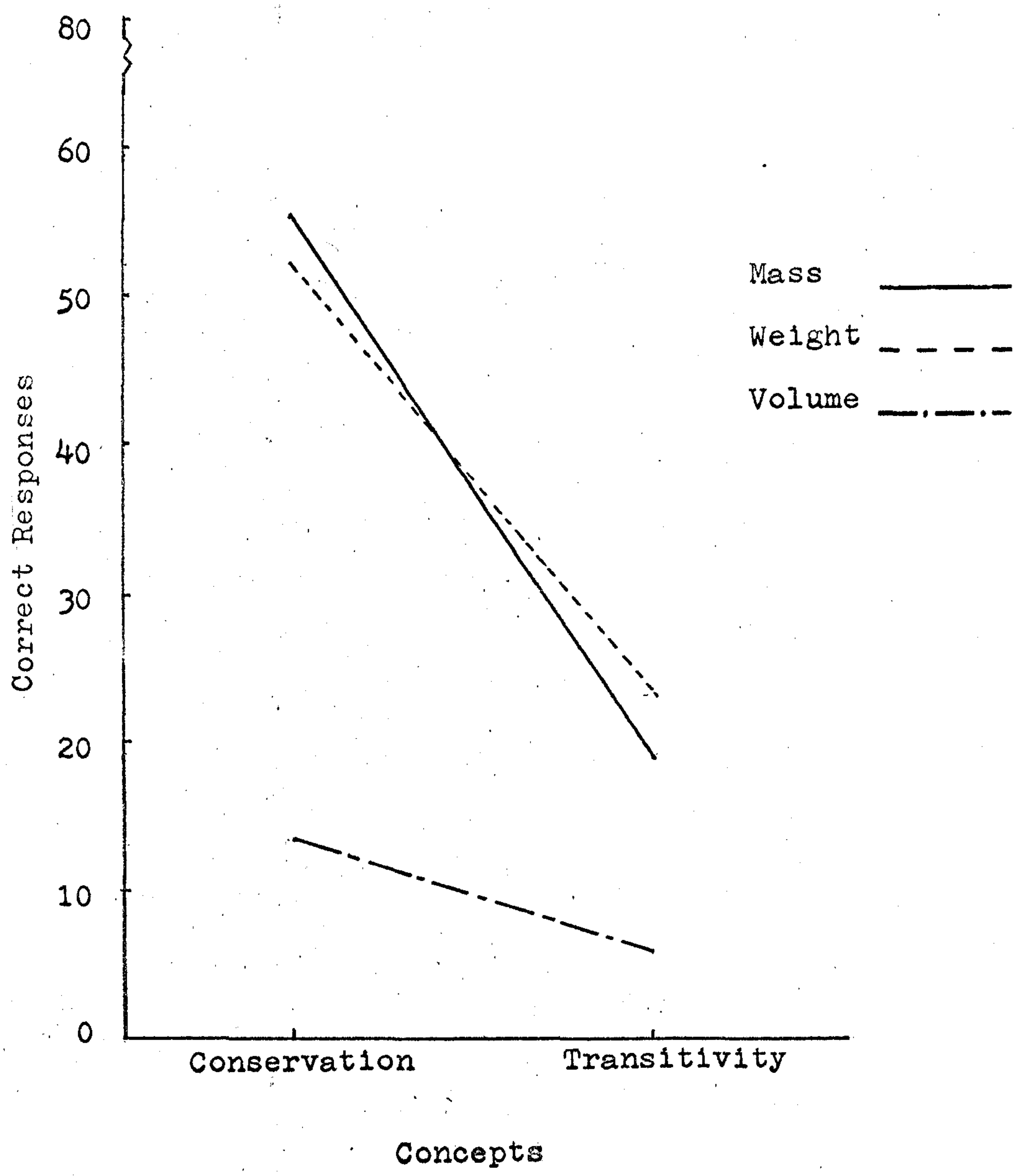

Figure 7 : Profile of simple effects for concept by property interaction.

data for these calculations is given in Appendix C, and is plotted in a profile illustrating the grade by concept interaction (Figure 8). This profile illustrates a simultaneous development for the concepts of conservation and transitivity in grades two and four, and a parallel increment between conservation and transitivity in grades six and eight. In grades six and eight conservation was more highly developed than transitivity.

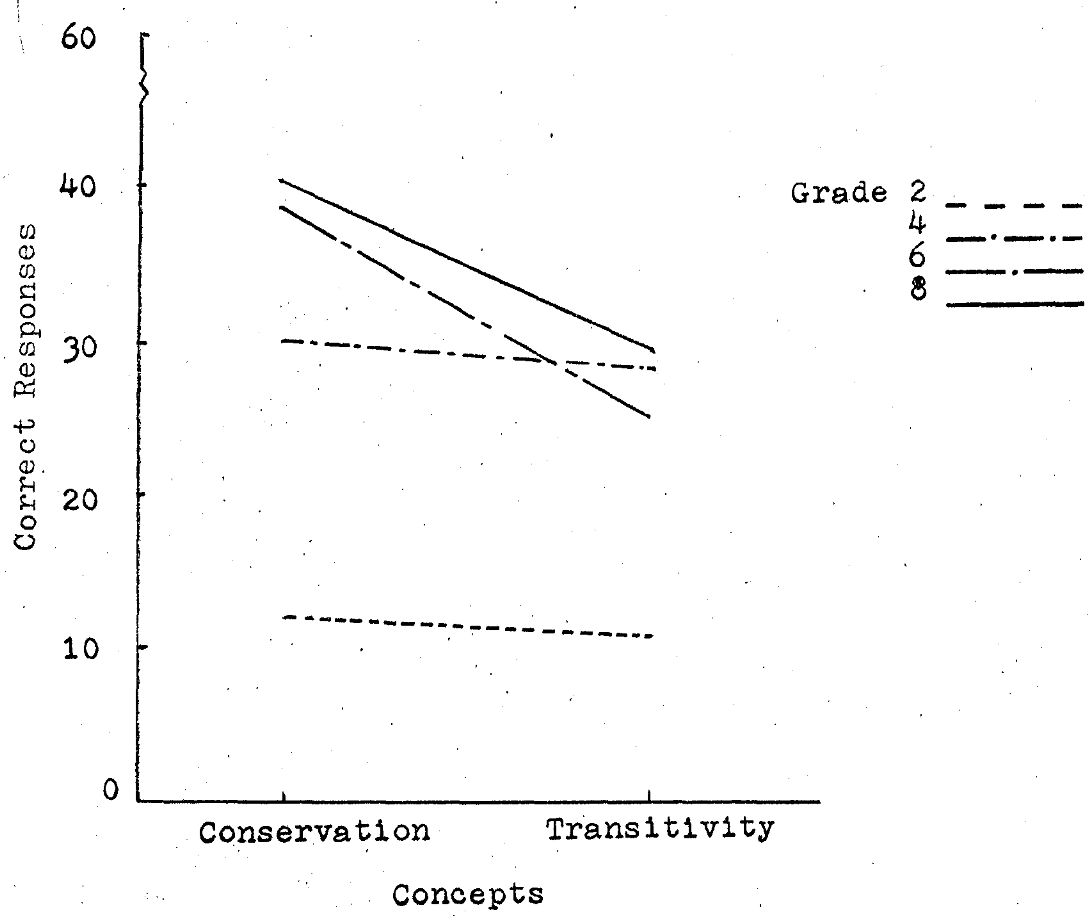

Figure 8 : Profile for grade levels by conservation and transitivity with material of one density.

CHAPTER IV

DISCUSSION

In the first chapter it was hypothesized that the cognitive operations of conservation and transitivity developed simultaneously for the properties of mass, weight and volume : that the development of the properties followed a regular order of mass, before weight, before volume : and that the concepts of conservation and transitivity developed earlier in females than in males.

While the major concern in this study is the comparison of the development of the concepts of conservation and transitivity, the results of the investigation of the individual concepts are first discussed. The reason is that the consideration of the individual concepts will provide an appropriate "ground work" for the discussion of the combined effect of the two concepts.

Conservation

An analysis of the data for conservation revealed a development of this concept between grades two and eight. However, it was found that this development was more accelerated between grades two and four, than between grades four and eight. This decrease in the rate of development was such that it suggested that by grade eight, the development of conservation was approaching an asymptote.

Further analysis of the individual properties of mass, weight and volume revealed that in grade two, there was no difference between these three properties in the level of their attainment. However, between grades two and four (approximately aged seven to nine), the development of the conservation of mass and weight was rapid. Approximately 70 per cent of the subjects had developed these two properties by grade four. Only <u>three</u> subjects had developed the property of volume in grade four (N = 20), and <u>six</u> in grade eight (N = 20). These results are similar to Elkind's (1961a) who found that approximately 75 per cent of the subjects had acquired the conservation of mass and weight somewhere around the seven to nine years period. He also found that the 75 per cent level for the development of conservation of volume occurred at about 17 years of age. Since the average age of the grade eight subjects in the present study was only <u>13.3</u> years a further comparison with Elkind's data on the conservation of volume could not be provided.

The present investigation further revealed that in grades 4, 6 and 8, the properties of mass, weight and volume formed some hierarchy of development. At these grade levels the property of volume was always the least developed. However in each grade, some children had developed the properties of mass and weight at the same time, and others had developed the property of weight before mass. Hence the development of these two properties did not form the unvarying relationship (i.e. mass before weight) found by Piaget (Piaget and Inhelder, 1941), and hypothesized in the present investigation.

Sex differences had not been accounted for in the previous studies by Piaget (Piaget and Inhelder, 1941) and Smedslund (1961). Sex differences were apparent in the present investigation. Females developed the concept of conservation earlier than males (i.e. in grade two). This observation supports the first half of hypothesis (C), that the development of conservation (and transitivity) occurs earlier in females than in males. Nevertheless, this early sex difference became negligible with increasing grade level.

Transitivity

An analysis of the transitivity data revealed that the trend of development for transitivity was different from that for conservation. The comparison of correct responses for grades indicated that the development of the transitivity concept increased significantly between grades two and four, and not between grades four and eight. However, a linear trend suggested that unlike conservation, the development of transitivity for materials of two densities was not yet approaching an asymptote. This offered the first indication that the concepts of conservation and transitivity did not develop simultaneously in the sample of children tested.

In grade two and grade eight, the development of transitivity of the properties of mass, weight and volume did not indicate any hierarchical arrangement. In grades four and six the three properties were developing in the same way as those of conservation. In other words, the property of volume was the slowest to develop, and the development of mass before weight was not invariable.

Although the influence of sex differences in the development of transitivity was negligible in grades 2, 4 and 6, males performed significantly better than females in grade eight. The greatest factor contributing to this sex difference was the level of the development of the volume property. Although 50 per cent of the males had developed transitivity of volume, the development of this property had not yet occurred in females. Further reference to sex differences in the development of the transitivity of volume will be made in the discussion of the combined effects of the development of conservation and transitivity.

Conservation and Transitivity

The analysis of the combined concepts of conservation and transitivity afforded the opportunity to compare the development of these two concepts. The results indicated that the development of these two concepts was evident with increasing grade level for both sexes. However, there was no significant difference between females and males in the development of the combined concepts from grades two to six. The results of this combined effect thus failed to support hypothesis (C) that the development of the concepts of conservation and transitivity occurred earlier in females than males. However, at the grade eight level, males performed significantly better than females on the combined concepts.

The results indicated no significant difference at each grade level for the combined concepts of conservation and transitivity, between the development of the properties of mass and weight. There was a significant difference at each grade level, between the property of volume and the combined properties of mass and weight. The volume property showed no signs of development between grades two and four, and four and six for either conservation or transitivity. However, there was a significant increase in its development between grades six and eight. Fifty per cent of the males had developed the property volume for both conservation and transitivity in grade eight ; only ten per cent of the females in grade eight had developed the conservation of volume, and no girls had yet developed the transitivity of volume. This accelerated development in males for the conservation and transitivity of volume provides a solution for the superior performance of males over females at the grade eight level.

This delayed development in females of the volume property, was also noted in Elkind's research (1961a). He found that 75 per cent of his sample of 469 children did not develop the conservation of volume until age 17. He also found that the percentage of boys was consistently higher than the percentage of girls who had developed the conservation of volume. Although his study considered only conservation, the results of the present investigation suggest that the development of the transitivity of volume follows a trend similar to conservation. Elkind attributed sex differences for the volume property to "differences in experience and opportunity for developing quantity concepts" (p. 558). He indicated that in adopting their masculine roles, males were more "mechanically minded" and had more experience in measuring and building things. On the other hand females were more concerned with their feminine roles of social interaction in the environment. Consequently males would be more proficient than females with the abstract relations involved in the volume property. An example, from the present study, of one response given by a boy in grade eight seems to support this view : "If you took them in cubic inches and measured them, they would be the same ".

The present investigation revealed that at all grade levels, conservation developed earlier than transitivity. This does not support Piaget's theory (Piaget and Inhelder, 1941) or hypothesis (a) which concerns the simultaneous development of the concepts of conservation and transitivity. Several suggestions may be offered to account for this discrepancy of results. Piaget conducted some studies with materials of several densities (Piaget and Inhelder, 1941, chap. V, VIII), and reported that the conservation of mass, weight and volume also involved the ability to conserve these properties with materials of different densities. At the stage of conservation of mass, "an elementary atomism appears to explain the permanence of the substance after ... the visible distortions" (1941, p. 168). The child bases his conception of the differences in density on "that which is inside" (p. 168). The stage of conservation of weight is marked by "successive explanations of density by corpuscular composition'that which corresponds to a more or less "fullness", and that which procedes from the schema of compression and decompression" (p. 173). However the ability to manage volume problems is "precisely the culmination of the schema of compression and decompression" (p. 183), which is for Piaget the "sine qua non" for the ability to conserve the properties of materials of several densities. Piaget concluded that "the notion of density thus appeared as a relationship between internal mass and apparent volume" (p. 184). Since the ability to conserve mass and weight of materials of two (or more) densities is fully attained only with the development of the volume property, this would suggest that the conservation of mass and weight of materials of two densities would not be as precise or as fully developed at lower grades as that of one density. This would further suggest the possibility of a simultaneous development of conservation and transitivity with materials of the same density. Inspection of Figure 8 gives some evidence of this possibility. This profile indicates a simultaneous development in grades two and four in the conservation and transitivity tasks involving only "plasticine" balls (i.e. one density). On the basis of this observation it is suggested that the use of materials of two densities might have retarted the apparent development of transitivity in this study.

A second possible solution for the slower development of transitivity is found in the work of McLaughlin (1963). Using the norms of the digit span test of the Wechsler Intelligence Scale for Children, he concluded that at Piaget's level of concrete operations, the child's memory span was sufficient to enable him to perform the simplest syllogism : A = B, B = C then A = C. "However if this kind of reasoning is applied to other premisses, it may produce invalid conclusions" (McLaughlin, 1963, p.67).

The transitivity task used in the present study involved not only those premisses related to the plasticine balls (A = B, B = C then A = C), but also those implying a relation between balls of a different density (B = P then A = P). The conservation task, on the other hand, involved only the judgment between a round and distorted ball of plasticine. It is therefore suggested that the difference in the development of the concepts of conservation and transitivity found in the present study might be a function of the number of premisses implied in each concept.

Suggestions for Future Research

It was suggested in this chapter that the difference in the development of conservation and transitivity in the sample of children used may have been influenced by the fact that the transitivity task involved materials of two densities, while the conservation task involved material of one density. Figure 8 gave some evidence of a simultaneous development of the two concepts in grades two and four when only those correct responses which referred to plasticine were considered. One suggestion for future research is to compare the development of these two concepts using materials of two densities for both conservation and transitivity tasks.

One variable which was not controlled in this study was the degree of learning and experience with the particular materials used. A discussion prior to the tests of each child revealed that most of them had used plasticine at one time or another. However, only a few children had more than "visual encounters" with window putty. The extent of their experience with this material was their knowledge that their "father used it to put on windows". It is therefore suggested that in future research a more familiar substance be used in place of window putty, (i.e. mud or clay).

Another problem, encountered in the scoring of responses, was that many children may have intuitively seen the true relationships in conservation and transitivity, but were unable to "verbalize" them. In other words, the behavioural modality used, may have masked the actual cognitive development of the two concepts. Braine (1954) found that non verbal techniques facilitated "inferential" responses in children (i.e. A is longer than B, B is longer than C, then A is longer than C). However, a recent study by Halpern (1962), showed no difference between verbal and non verbal techniques. On the basis of this conflict of results, it is suggested that additional research be conducted on verbal and non verbal techniques, in investigating the development of conservation and transitivity. The verbal techniques could be similar to those employed in the present study. The non verbal techniques could involve manipulation of the materials by the child rather than the experimenter.

In a recent revision (Piaget and Inhelder, 1961) of his early work, Piaget concluded that the concepts of conservation and transitivity might be employed as tasks for measuring intelligence. Since the age of development of such concepts may give evidence of "task specific" dimensions of intelligence, it cannot be assumed to measure intelligence in general. In future research, it would be possible to investigate the age of development of these two concepts over different tasks and levels of intelligence, as measured by standardized intelligence tests.

CHAPTER V

SUMMARY

The present study was concerned with the proposed simultaneous development of conservation and transitivity of mass, weight and volume, as measured over grades 2, 4, 6 and 8. Sex differences, with regard to these concepts, also served as experimental variables. The procedure adopted was a modification and extension of Smedslund's, which revealed no simultaneous development between the conservation and transitivity of weight.

On the basis of inconsistencies in the procedure employed by Smedslund, the simultaneous development was proposed. It was further predicted that the properties of the two concepts formed a hierarchical stratum of mass, before weight, before volume. On the basis of previous research indicating the superior performance of females in the early grades, it was proposed that the development of conservation and transitivity occurred earlier in females than in males.

Four groups of 20 subjects (10 males and 10 females) in grades 2, 4, 6 and 8 were selected from a separate school on the basis of average school achievement.

The subjects were individually tested in two sessions on systematically varied tasks of conservation and transitivity. The conservation tasks involved the comparison of a round plasticine ball with a distorted ball, with respect to its properties of mass, weight and volume. The transitivity tasks involved the comparison of equal relations of round and distorted plasticine balls : A = B, B = C then A = C ; followed by the inclusion of a putty ball (P) : B = P then A = P.

The first hypothesis in the study was not supported. The results indicated that at all grade levels, the concept of conservation using one density developed earlier than transitivity using two densities.

The results did not support the second hypothesis. Although the volume property developed last, the development of the properties of mass before weight were not found to be invariant.

Only the first half of the third hypothesis was confirmed, i.e. the development of conservation occurred earlier in females than males. However, on the transitivity concept and on the combined effect of the two concepts, the males were found to be more proficient at the grade eight level.

Suggestions for future research were discussed.

APPENDIX A
RAW DATA

	Ss.	Conservation Mass	Conservation Weight	Conservation Volume	Transitivity Mass	Transitivity Weight	Transitivity Volume	Totals
	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	1	1	1	0	0	0	3
	4	1	1	0	0	0	0	2
	5	0	0	0	0	0	0	0
Female	6	1	0	0	0	0	0	1
	7	1	1	0	01	1	0	3
	8	1	0	0	0	0	0	1
	9	0	0	1	0	0	0	1
	10	0	0	0	0	0	0	0
Grade 2								
	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	1	0	0	0	0	0	1
	5	0	0	0	0	0	0	0
Male	6	0	1	0	0	0	0	1
	7	0	0	0	1	1	0	2
	8	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0
	1	0	1	0	1	1	0	3
	2	1	1	1	1	0	0	4
	3	1	0	0	0	1	0	2
	4	1	0	0	0	0	0	1
	5	0	1	0	0	0	0	1
Female	6	1	1	1	1	0	0	4
	7	0	0	0	0	0	0	0
	8	1	1	0	0	1	0	3
	9	1	1	0	0	0	0	2
	10	0	1	0	0	0	0	1
Grade 4	1	1	0	0	0	0	0	1
	2	1	1	0	0	0	0	2
	3	1	1	0	1	0	0	3
	4	1	0	0	0	0	0	1
	5	1	1	0	1	1	0	4
Male	6	0	1	0	0	0	0	1
	7	0	0	0	0	1	0	1
	8	1	1	1	1	1	1	6
	9	1	1	0	0	0	0	2
	10	0	1	0	1	1	0	3

Continued

			Conservation			Transitivity			Totals
		Ss.	Mass	Weight	Volume	Mass	Weight	Volume	
Grade 6	Female	1	1	1	0	0	0	0	2
		2	1	1	1	1	1	0	5
		3	1	0	0	0	0	0	1
		4	0	0	0	0	0	0	0
		5	1	1	0	1	0	0	3
		6	1	1	1	0	0	0	3
		7	1	1	0	0	1	0	3
		8	1	1	0	0	1	0	3
		9	1	1	0	1	1	0	4
		10	1	1	0	0	0	0	2
	Males	1	1	1	0	0	0	0	2
		2	1	1	0	1	0	0	3
		3	1	1	0	0	0	0	2
		4	1	1	0	0	0	0	2
		5	1	1	0	1	1	0	4
		6	1	1	0	0	0	0	2
		7	1	0	0	0	0	0	1
		8	1	1	0	1	1	0	4
		9	1	1	0	0	0	0	2
		10	1	1	0	0	0	0	2
Grade 8	Female	1	1	1	0	0	0	0	2
		2	1	1	1	1	1	0	5
		3	1	1	0	0	0	0	2
		4	0	0	0	0	0	0	0
		5	1	1	0	0	0	0	2
		6	1	1	0	0	0	0	2
		7	1	1	0	0	1	0	3
		8	1	1	0	0	0	0	2
		9	1	1	0	0	0	0	2
		10	0	1	0	0	0	0	1
	Male	1	1	0	0	0	0	0	1
		2	1	1	0	0	0	0	2
		3	1	1	1	0	0	1	4
		4	1	1	1	1	1	1	6
		5	1	1	0	0	1	0	3
		6	1	1	1	1	1	1	6
		7	1	1	0	1	1	1	5
		8	1	1	1	0	1	0	4
		9	1	1	1	1	1	1	6
		10	0	0	0	0	0	0	0
						Grand Total			168

APPENDIX B

Data for Percentage of Agreement Among Judges

Criterion : 3 agreements = 1
2 agreements or less = 0

		Conservation			Transitivity			Totals
	Ss.	Mass	Weight	Volume	Mass	Weight	Volume	
Grade 2 F	1	1	1	1	1	1	1	6
	2	0	1	1	1	1	1	5
Grade 2 M	1	1	1	1	1	1	1	6
	2	1	1	1	1	1	1	6
Grade 4 F	1	1	1	1	1	1	1	6
	2	1	1	1	1	1	1	6
Grade 4 M	1	1	1	1	1	1	1	6
	2	1	1	1	0	1	1	5
Grade 6 F	1	1	1	1	1	1	1	6
	2	0	1	1	1	1	1	5
Grade 6 M	1	1	1	1	1	1	1	6
	2	1	1	1	1	1	1	6
Grade 8 F	1	1	1	1	1	1	1	6
	2	1	1	1	1	1	1	6
Grade 8 M	1	1	1	1	1	1	1	6
	2	1	1	1	1	1	1	6
							Total	93

N = 16

F = females
M = males

APPENDIX C

Transitivity Data
(Responses for material of one density)

		Grade 2			Grade 4		
	Ss.	Mass	Weight	Volume	Mass	Weight	Volume
Females	1	0	0	0	1	1	0
	2	0	0	0	1	1	0
	3	1	1	0	1	1	1
	4	0	0	0	0	0	0
	5	0	0	0	0	0	0
	6	0	0	0	1	1	0
	7	1	1	0	0	0	0
	8	0	0	0	1	1	0
	9	0	0	0	1	1	0
	10	0	0	0	0	0	0
Males	1	0	0	0	1	1	0
	2	0	0	0	0	0	0
	3	0	0	0	1	1	0
	4	1	0	0	1	0	0
	5	0	0	0	1	1	1
	6	1	1	0	0	0	0
	7	1	1	0	1	1	0
	8	0	0	0	1	1	1
	9	1	1	0	1	0	0
	10	0	0	0	1	1	0
Totals		6	5	0	13	12	3

		Grade 6			Grade 8		
	Ss.	Mass	Weight	Volume	Mass	Weight	Volume
Females	1	0	0	0	1	1	0
	2	1	1	0	1	1	0
	3	1	0	0	0	1	0
	4	0	0	0	0	0	0
	5	1	1	0	1	0	0
	6	1	1	0	0	1	0
	7	1	1	0	1	1	0
	8	1	1	0	0	1	0
	9	1	1	0	1	0	0
	10	0	0	0	0	0	0
Males	1	1	1	0	0	0	0
	2	1	1	0	0	0	0
	3	0	0	0	1	1	1
	4	1	1	0	1	1	1
	5	1	1	0	1	1	0
	6	0	0	0	1	1	1
	7	1	1	0	1	1	1
	8	1	1	0	0	1	0
	9	0	0	0	1	1	1
	10	0	0	0	0	0	0
Totals		13	12	0	11	13	5

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