DOCUMENT RESUME

ED 064 345 TM 001 512

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TITLE Conservation and Achievement Test Performance among Fifth-Graders.

NOTE 20p.

EDRS PRICE MF-$0.65 HC-$3.29

DESCRIPTORS *Achievement Tests; *Conservation (Concept); *Criterion Referenced Tests; *Grade 5; Statistical Analysis; *Test Results

ABSTRACT

The relationship between conservation and achievement is examined on specific tests and test items on the Stanford Achievement Test Battery used in the elementary years. Specifically, performance on two tests (Word Meaning and Arithmetic Concepts) were analyzed according to subjects level of thinking (concrete or formal) for total score, individual items, number of items omitted, IQ, and sex. The subjects were 48 fifth-graders ranked according to IQ scores, with an equal number of males and females at each IQ score (range from 82 to 150) and ranging in age from 10.33 to 12.42 years (average 10.96). In addition to the Stanford Achievement tests, tests of conservation were administered individually, using Piaget's traditional clay tasks first and then Lovell and Ogilvie's (1960) procedure for testing conservation of volume using solids, bricks and water. Subjects were classified on the formal level if they met Piaget's criterion of formal level on the clay task and Lovell and Ogilvie's criterion for the conservation of volume tasks. Subjects were classified as concrete if their judgments were based on perceptual differences rather than understanding of abstract relationships. A Chi Square test of independence between level of thinking and achievement test performance showed superior performance by those on the formal level on total score for Word Meaning and Arithmetic Concepts. (Author/DB)

CONSERVATION AND ACHIEVEMENT TEST PERFORMANCE AMONG FIFTH-GRADERS[1]

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Achievement test performance is a function of many factors such as intelligence, socioeconomic status and teacher expectation. (Brophy and Good, 1970; Conley, 1970; Montague, 1964.) The effect on achievement of certain of these factors has been extensively explored; the effect of others, such as level of thinking has not. The ability to conserve, i.e., to recognize the invariance of an empirical factor such as weight after an irrelevant transformation, develops as a child develops logical thinking which, in turn, parallels the development of certain competencies in subject matter areas such as reading and mathematics. (Copeland, 1970; Elkind, 1970; and Sigel, 1969.) As such, differences in logical thought may well affect the validity of standard achievement tests in these areas.

If a high score on an achievement test can be shown to indicate superior learning performance when confronted with a practical problem in everyday life, the test can be said to have external validity. In practice, most achievement tests have, only, content validity, since they are developed to cover material presented in the most widely used texts. The test publisher assumes the teacher will decide whether performance on a standardized test is predictive of actual performance, but the teacher assumes that the test publisher has already established this relationship. The teacher then has the dual responsibility of choosing the best achievement test available, and also of understanding all those factors which affect student performance. Since the actual significance of achievement test scores is frequently assumed rather than established, exploring additional factors influencing achievement test performance is particularly important because of the decisive impact these scores have on a child's future. This research was undertaken to further investigate one of those factors, that is, the relationship between student's level of thinking and achievement test performance.

A number of recent studies have examined the relationship between conservation and achievement for young children, kindergarten through the second grade, during which period most children move from the preoperational stage toward the period of concrete operations. Crutchfield (1970) studied 30 M and 30 F from six kindergarten classes to determine whether a conservation training program would help reading readiness. Although the conservation training program did not result in clearly superior readiness, the study did demonstrate a highly significant correlation between conservation ability and reading readiness ($p < 001$).

Using both a group paper and pencil test and an individual test, Nelson (1970) used conservation of number and length to predict arithmetic achievement among first-graders. Ss level of thinking was assessed in early September. Four months later arithmetic achievement was assessed. All correlations, for both the group and individual tests, showed a significant relationship between conservation and arithmetic achievement test performance ($p < 001$).

Lambert (1970) found no significant relationship between conservation of quantity and Stanford Achievement tests of Word Meaning and Paragraph Meaning among first-graders. She did, however, find a significant relationship between Word Meaning and tasks requiring drawing from a different perspective, and assessing water level in a tilted jar.

LeBlanc (1971) studied the relationship between conservation of number and solving arithmetic subtraction problems among first-graders. He found that children who showed higher level conservation demonstrated superior performance and that conservation of number was a better predictor of success in problem solving than group IQ.

In a longitudinal study of middle class children, kindergarten through second grade, Almy, Chittenden and Miller (1967) found low correlations between conservation and reading growth ($r=.37$), and between conservation and mathematics concepts ($r=.53$). For lower class children, who lagged behind the middle class children in development, these correlations were .39 and .38, respectively.

In two separate studies, Goldschmid (1967, 1968) tested children in grades kindergarten through two and found a significant relationship between conservation and a number of achievement variables, including vocabulary, arithmetic, social studies and science. From this and other studies cited above it appears that during the ages at which the ability to conserve is being established, there is a positive relationship between conservation and achievement.

Additional studies have expanded this investigation to include Ss at the concrete operational level of thinking, as well as the preoperational level. Hutson (1971), for example, investigated the relationship between logical development and comprehension of syntax using children ages five to eight. Conservation was found to be strongly related to syntactical comprehension, and the author concluded that this was due to the development of logical reasoning between ages five and eight.

Gottfried (1969) designed a screen utilizing a series of lights and knobs which allowed children to match a model with one of several choice pictures. For ages six to nine, success with this problem was related to conservation of length ($p < .01$) but not to conservation of number. Mycock (1969) also tested nine year-olds, in a junior school in England. Results revealed a substantial correlation between Piagetian tasks and two standardized tests, i.e., Primary Verbal 1 and Non-Verbal 5. Piagetian spatial tasks, however, did not have a high correlation with the Science Research Associates Space Test.

Using Freyberg's concept test, a set of group administered tasks similar to Piagetian conservation tasks, Kaminsky (1971) studied the relationship between conservation and arithmetic achievement. For students in grades two and three, she found a significant correlation between the concept test and Stanford Achievement Arithmetic Concept scores ($r=.81$, $p < .01$). Thus, the above studies also reveal some relationship between Piagetian tasks of conservation and certain measures of achievement for Ss thinking at the concrete operational level.

Other studies have tested Ss thinking at the formal as well as concrete operational level. Conley (1970), for example, investigated the relationship between conservation, socioeconomic status and achievement. For six to ten year olds, she found low, but significant r's ($p < .05$) between conservation and total grade point average ($r=.43$), reading grade point average ($r=.45$), mathematics grade point average ($r=.35$), Iowa Test of Educational Development total score ($r=.28$), Iowa Reading score ($r=.30$) and Mathematics score ($r=.29$).

Conservation performance was compared with Stanford Achievement Test performance by Sams (1969) for Pima Indian and Caucasian children in fifth and sixth grades. He found that after statistical adjustments for differences in intelligence levels, there were no significant differences between conserver and nonconserver on the Stanford Achievement tests of Arithmetic Concepts, Arithmetic Applications and Arithmetic Facts.

In contrast to Sam's findings, Silliphant (1969) found a significant relationship for fifth graders between conservation and Stanford Achievement test of Arithmetic Concepts, a non-significant relationship with Arithmetic Applications and no relationship to Arithmetic Facts. In addition, Cleminson (1971) compared fifth grade performance on science related Piagetian tasks for three different science programs. Although there were no differences by program, results demonstrated a moderate relationship between the science tasks and both the Iowa Tests of Basic Skills and the Sequential Tests of Educational Progress. Cleminson concluded that the Piagetian tasks and the standardized tests measured somewhat different cognitive abilities.

Keller (1969) studied the relationship between conservation performance and concept attainment for sixth graders on the concrete and formal level. She found a significant relationship between concept attainment and cognitive level as measured by the Lodwick test ($p < .05$) and conservation ($p < .05$), with the formal group performing more efficiently than the concrete group.

Sheehan (1970) studied the effect of formal versus concrete instruction on achievement. Phrasing instruction in both formal and concrete terms for students on both levels, he found that formal students demonstrated superior performance regardless of type of instruction. Moreover, concrete instruction was more effective for both groups, and achievement by formal students more durable than that of concrete students. Thus, with the exception of Sams (1969), a consistent relationship was found between conservation and achievement for Ss on the concrete and early formal levels of thinking.

In summary, the literature reveals an increasing interest in the relationship between conservation and achievement, with findings suggesting a positive relationship between these two factors. The present study further examines this relationship on specific tests and test items on the Stanford Achievement Test Battery used in the elementary years. More specifically, performance on two tests (Word Meaning and Arithmetic Concepts) were analyzed according to Ss level of thinking (concrete or formal) for total score, individual items, number of items omitted, IQ, and sex. When compared with Ss on the concrete level, it was hypothesized that Ss on the formal level would receive higher total scores on Word Meaning and Arithmetic Concepts, and that they would choose different alternatives when answering an item incorrectly.

Method

Subjects

The fifth grade population was ranked according to IQ scores and a sample of 48 Ss selected having an equal number of males and females at each IQ score. The Ss ranged in age from 10.33 to 12.42 years with an average age of 10.96. IQ's ranged from 82 to 150 with an average score of 114.

Achievement Tests

The Stanford Achievement tests of Word Meaning and Arithmetic Concepts (Form W, Intermediate II) were administered to the students as a group. Word Meaning required 12 minutes, Arithmetic Concepts 20 minutes.

Conservation Tasks

Tests of conservation were administered individually using Piaget's traditional clay tasks first and then Lovell and Ogilvie's (1960) procedure for testing conservation of volume using solids, bricks and water. In the clay task, one of two equal amounts of clay was varied and S was asked whether the new shape was larger, (heavier, or would require a larger container to hold it), equal in size to the other piece of clay, or smaller (lighter, or would require a smaller container to hold it). The shape of the altered piece of clay was varied a number of times. After the student replied, he was asked how he decided upon his answer. Each correct conservation was scored as one point. Thus, a total of nine points could be earned on the clay task.

Conservation of volume was also tested using plastic bricks and beakers of different sizes as described by Lovell and Ogilvie. Each S was asked to judge comparative volumes of different three dimensional arrangements of the same number of plastic bricks. Occupied volume was tested by asking S to anticipate whether lowering bricks into beakers of differing sizes filled with water would cause overflow; if so, would varying the configuration of the same number of plastic bricks, make the overflow more, the same or less. Conservation of displacement volume was measured by lowering bricks into an empty beaker and asking the student to anticipate whether water would have spilled, if the beaker had been full of water, and to compare the overflow (if anticipated) when the configuration or weight of the bricks was varied.

The order of questions was the same for all students, starting with the simplest tasks, conservation of mass, and progressing to the most difficult, conservation of volume according to displacement. Ss were classified as on the formal level if they met Piaget's criterion of being on the formal level for the clay task (conservation on all three tasks), and Lovell and Ogilvie's criterion for the conservation of volume tasks. Ss were classified as concrete if their judgments were based on perceptual differences rather than understanding of abstract relationships.

Ss not clearly in either of these two groups were classified as transitional and were eliminated from the study since purpose was to contrast the two extremes. Inspection of the testing records showed that those classified as concrete grasped only the simpler relationships and never complete mastery of conservation of volume. Those classified as formal mastered everything normally included as formal thinking in this area.

Results

A Chi Square test of independence between level of thinking (formal and concrete) and achievement test performance (above and below the median) revealed superior performance by those on the formal level on total score for Word Meaning and Arithmetic Concepts.

TABLE 1

Achievement Test Performance by Level of Thinking for Word Meaning and Arithmetic Concepts

	Word Meaning[a]		Arithmetic Concepts[b]	
	Lower ½	Upper ½	Lower ½	Upper ½
Concrete	13	6	13	6
Formal	5	11	4	12

[a] $x^2 = 5.04$; df= 1, $p < .05$ [b] $x^2 = 7.59$; df= 1, $p < .01$

The frequency data in Table 1 show that level of thought is not independent of achievement; the formal group scored higher than the concrete group on both tests.

Performance on each item (correct and incorrect) was next examined by level of thought to determine whether difference in total score could be related to specific items, or to superior performance in general by those at the formal level. Chi Square tests revealed that for 15% of the items on Word Meaning and 19% of the items on Arithmetic Concepts there was a significant relationship between level of thinking and whether or not the item was answered correctly ($p < .05$). While these percentages are small, the results are consistent with subsequent analyses.

The item analysis was then extended to examine alternatives chosen when answering incorrectly, by level of thought. For each item the frequency of each wrong alternative was determined separately for the concrete and formal groups. The two lowest frequencies in each group were then combined to yield a 2 way table (level of thinking X alternative chosen). Fisher Exact tests for each item revealed that choice among incorrect alternatives was not independent of level of thought on 18% of the items for Word Meaning and 6% of the items for Arithmetic Concepts.

Statistical analysis of number of incorrect alternatives chosen as a function of level of thought is made difficult by the fact that there are slightly more students in the concrete group (19 as compared to 16 in the formal group), and those in the formal group made fewer incorrect choices. To minimize these limitations, therefore, the number of incorrect alternatives chosen at least once was determined separately for the concrete and formal group for each test. The Word Meaning examination had a total of 144 wrong alternatives (48 items X 3 wrong alternatives/item), whereas Arithmetic Concepts had a total of 96 (32 items X 3 wrong alternatives/item).

TABLE 2

Number of Incorrect Alternatives Chosen at Least Once by Level of Thinking

	Incorrect Alternatives Chosen			
	Word Meaning[a] (48 items)		Arithmetic Concepts[b] (32 items)	
	N	%	N	%
Concrete	110	76	84	88
Formal	75	52	72	75

[a] $z = 13.33;\ p < .001$ [b] $z = 7.26;\ p < .001$

Table 2 reveals a significant difference between the concrete and formal groups in the number of incorrect alternatives chosen at least once for both tests ($p < .001$).

The difference in number of items attempted was next analyzed to determine whether the superior performance of the formal group could be due to having attempted more items.

TABLE 3

Number of Items Attempted by Level of Thinking

	Word Meaning[a]		Arithmetic Concepts[b]	
	Lower ½	Upper ½	Lower ½	Upper ½
Concrete	12	7	10	9
Formal	6	8	7	9

[a] $x^2 = .565;\ df = 1;\ p > .05$ [b] $x^2 = .292;\ df = 1;\ p > .05$

Table 3 shows no significant difference in number of items attempted by the concrete and formal groups for either test.

To determine whether level of thinking affected performance on the two tests differentially, the number of concrete vs. formal Ss above the median on each test was determined (see Table 4).

TABLE 4

Performance Above the Median by Level of Thinking

	Word Meaning Upper ½	Arithmetic Concepts[a] Upper ½
Concrete	6	6
Formal	11	12

[a] $x^2 = .0830$; df= 1; $p > .05$

A Chi Square test of independence revealed that the tests were not significantly different in the number of Ss above the median performance for each level of thinking.

To assess whether differences in achievement test performance were a function of IQ, the number of Ss above and below the median IQ (Otis-Lennon Mental Ability Test) were determined for the concrete and formal groups. As shown in Table 5, a Chi Square test of independence between these two variables revealed no significant difference in the number of Ss above the median IQ for the formal and concrete groups. Apparently the differences in achievement test performance as a function of level of thinking cannot be attributed to IQ in this study. Nor can they be attributed to sex differences, for the number of males and females at each level of thinking was not appreciably different.

TABLE 5

IQ Above the Median by Level of Thinking

	IQ[a]	
	Lower ½	Upper ½
Concrete	11	8
Formal	7	9

[a] $x^2 = .66$; df=1; $p > .05$

Discussion

The results of this study suggest that Ss who are on the formal level with respect to conservation perform at a higher level than do those on the concrete level, on tests of a widely used achievement bettery. This could not be attributed to differences in IQ or sex. Item analysis by level of thought revealed that some correctly answered items, as well as some incorrectly chosen alternatives were related to level of thought. Pupils on the concrete level chose more distractors, and chose them more often than did those on the formal level. There was no significant difference in the number of items attempted. Neither Word Meaning nor Arithmetic Concepts appeared to be more sensitive to differences in level of thinking. Further research is needed to discover whether the superior performance of the formal group is due to greater speed in focusing on relationships, abstracting distinguishing characteristics, and ruling out wrong alternatives, as much as specific item content.

Construction of separate keys for those on the concrete and formal level may provide the teacher with more meaningful achievement scores, and enable her to direct her teaching program more effectively to the student's level of thought. Level of logical thought gives the teacher an idea of how the child thinks at a given time, enabling her to present the appropriate learning experience in a way in which the child can understand. As Flavell

(1963) stated in discussing the contributions of Piaget, "If you have a rough idea of what children at a given developmental level are likely to be thinking about and how they are likely to be thinking about it; if you have even crude guidelines as to what the child can and cannot grasp, and how he will and will not be able to construe events, then you can better predict what he will say and do next, and in general carry out your caretaker function with greater confidence and skill." (Flavell, p. 419)

Footnotes

1. This study was conducted with the permission and support of Dr. William Nunan, Superintendent and Mr. Francis Spera, Principal, Toll Gate School, Hopewell Valley Regional Schools, Pennington, New Jersey.

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