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THE INFLUENCE OF CONCRETE AND FORMAL MENTAL STRUCTURES ON COLLEGE STUDENT ACHIEVEMENT AND ATTITUDES

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ABSTRACT

Two classes of preservice elementary science teachers were classified as concrete operational or formal operational based upon Piagetian-type tasks. Seven concrete and seven formal students were randomly selected from each class and assigned to two instructional sequences: first, concrete to abstract; and second, abstract to concrete. Achievement and attitudes were measured. Formal operational students achieved significantly more regardless of the sequencing or tasks evaluated, but no significant differences were noted in attitudes between the groups with both groups indicating favorable attitudes toward instruction.

INTRODUCTION

Jean Piaget studied the intellectual development of children and young people for over fifty years. He identified four broad categories of cognitive development which were named: sensori-motor (0-2 years), preoperational (2-7 years), concrete operational (7-11 years), and formal operational (11-15 years). The assumption that mental structures can be identified through observable behavior is fundamental to Piaget's theory, but their growth is not random.

Piaget also presumed that there were four influential factors in a child's progression through these four major stages: 1) maturation contributes in the form of neurological growth; 2) experience with the physical environment is necessary; 3) social interaction, the exchanging of ideas among people, is necessary; and 4) equilibration as an internal regulating system balances the other three factors (Kolodity, 1974).

This discussion will focus on the latter two stages of cognitive development, the period of concrete operations and the period of formal operations.

PREVIOUS STUDIES

Piaget has indicated that students initiate formal operations around junior high school age and are fully formal operational thinkers at about the sophomore or junior year in high school. A number of researchers have challenged this assumption. For example, in two studies involving junior high school students, 77% and 83% respectively were found to be concrete operational (Nordland, et. al., 1974, Renner and Stafford, 1972). Four additional studies involving high school students, grades 10-12, indicated that most students at this level lacked formal operational thought (Nordland, et. al., 1974, Renner and Stafford, 1972, Lawson and Blake, 1974, and Chiappetta and Whitfield, 1974).

TABLE 1. *Piagetian Characteristics of Two Levels Of Intellectual Development.*

Concrete Operational Thought	Abilities to classify, combine, order, separate, seriate, multiply and divide, reversible thinking; Conservation ("real understanding") of length, matter, weight, and volume; Concept of reversibility begins to develop; An awareness of variables; Can only apply logic to problems involving concrete (real or observable) situations.
Formal Operational (Abstract) Thought	Ability to deal with hypothetical problems; Can reflect on own thinking; Can perform controlled experiments; Can reverse direction between reality and probability.

College students have also been assessed for formal thinking and McKinnon and Renner (1971) and Lawson and Renner (1974) discovered that 50% were concrete operational with 25% and 22% respectively at a fully formal operational level. Juraschek (1974) found a differentiation among college students with 48% of 141 elementary education majors classified as formal operational. A lack of formal thinking in adults of other cultures was also confirmed by Dosen (1977).

Chiappetta (1976) reviewed several studies that also indicated that there is a regression effect that often occurs among students where basic operations are repeated at different levels of functioning. Regression, i.e. from formal back to concrete, appears to occur when individuals are confronted with subject matter which is new to them. There is additional evidence that students having formal operational thought may profit from instruction which is

concrete oriented and this apparent fact may be related to the regression phenomena, especially if new concepts are being presented.

Evidence appears sufficient to conclude that not all college students are capable of formal operational thought, perhaps only one-fourth of entering freshmen. This assumption has even received some support from Piaget (1972) who conceded that formal thought may not be completely developed until age 20. If this is true, it has meaning regarding the manner in which instruction is provided for college students as well as the obvious implications for instruction at the secondary level. Additionally, if an instructor desires to assist students to develop cognitive capacities at the formal level, he/she will have to provide a "concrete" base of experiences. Although instructors cannot control maturation, they can be an intervening variable by providing direct experiences with the physical environment and directing the social interaction which occurs.

THE PROBLEM

The central issue is whether instructional intervention will affect learning after cognitive levels have been identified. More specifically, will students identified as concrete operational perform differently than formal operational students when provided with concrete experiences and abstract instruction in science methods classes? Also, assuming that success in learning affects attitudes, will concrete and formal operational students perceive instruction differently if it is provided at the concrete and abstract levels?

METHODS

Sample

Two of three elementary methods classes were randomly selected and students in the classes were given Burney's (1977) "Objective Formal Reasoning Instrument." On the basis of their scores, they were identified as concrete operational, transitional, and formal operational. Those identified as transitional were excluded from the study but remained in the classes. Of the four groups remaining, the smallest was seven formal operational students in one class. To achieve equal cell size, seven students were randomly selected from the two concrete and one formal groups remaining.

Hartley's test was applied to ACT composite scores prior to initiating the study and indicated homogeneity of variance, F max (4,27) = 2.71, p n.s.

Design

Three hypotheses were tested by achievement scores and two by an attitude measure: 1) achievement levels of concrete operational students will vary from those of formal operational students when instructed in concrete tasks; 2) achievement levels of concrete operational students will vary from those of formal operational students when instructed in abstract tasks; 3) achievement levels of both concrete and formal students who receive instruction sequenced in a logical order from concrete to abstract will vary from those of students who receive instruction not logically sequenced; 4) attitudes of students who received instruction in a logical sequence will vary from those who received instruction from abstract to concrete; 5) attitudes of concrete operational students will vary from those of formal operational students when: a) concrete instruction is received, and b) abstract instruction is received.

A 2 x 2 Factorial Analysis of Variance design was applied to two levels of cognitive development, concrete and abstract, for: 1) achievement—concrete tasks, abstract tasks, and total (both); and 2) attitude.

Treatments

1. Class one received instruction on concrete tasks involving skills of observation, classification, measurement, and collecting, communicating, and graphing data for five days; subsequently, the class received an additional five days of instruction on more abstract tasks of identifying and controlling variables, developing hypotheses, and designing experiments.

2. Class two received basically the same instruction, but received five days on abstract tasks first and then five days on concrete tasks.

Instruments and Administration

Achievement was measured on a paper-pencil test designed by the author which was presumed to have content validity because it was carefully matched to each process skill for which instruction was received. Scores were computed for concrete tasks, abstract tasks, and the total of both.

The Purdue Attitude Inventory, designed to measure attitudes toward any class, was administered twice. First, at the conclusion of the first five days of instruction and again at the end of the second five day period of instruction. Science methods were taught three times per week so total instructional time was slightly more than three weeks.

RESULTS

Students who were identified as formal operational scored significantly higher on achievement measures regardless of sequencing of instruction or type of instruction (concrete vs. abstract). Hypotheses one and two may be accepted but hypothesis three must be rejected because sequencing had no significant effect on achievement.

TABLE 2. *Analysis of Variance for a 2 x 2 Factorial Design.*

Achievement Measured for Instruction in Concrete Tasks				
Source of Variation	SS	df	MS	F
Levels	1386	1	1386	16.15***
Sequence	55	1	55	0.64
Levels x Sequence	296	1	296	3.45
Error	2060	24	85.8	

Achievement Measured for Instruction in Abstract Tasks				
Source of Variation	SS	df	MS	F
Levels	558	1	558	5.49*
Sequence	3	1	3	0.03
Levels x Sequence	31	1	31	0.30
Error	2440	24	101.7	

Achievement Measured for Instruction in Both Tasks				
Source of Variance	SS	df	MS	F
Levels	847	1	847	13.37**
Sequence	32	1	32	0.51
Levels x Sequence	4	1	4	0.06
Error	1520	24	63.3	

* $p<.05$
** $p<.01$
*** $p<.001$

Reasons or potential explanations for these results are not easy to state. A critical assumption is that the measurement to identify concrete and abstract or formal students was valid. It was discriminatory in that those students identified as concrete operational did achieve less than those identified as formal operational. This does not, however, explain why there was a significant difference in achievement on concrete tasks. These tasks were directly adapted from the *Science—A Process Approach* curriculum which was designed for grades K-6, and they certainly could not be considered difficult for a college population. The achievement measure was not statistically analyzed, but it was assumed to have face validity in that tasks were directly designed to measure process skills as were the pass-fail competency measures. Although some degree of skepticism might be acceptable, I do not believe that this was the source of any significant differences. The only reasonable conclusion appears to be that students iden-

tified on Burney's measure as formal operational are likely to achieve more highly than those who are identified as concrete operational, regardless of the instruction received.

No significant differences in attitudes were noted regardless of the mix of operational levels and tasks. Hypotheses 4 and 5 should be rejected. Positive attitudes were shown toward instruction by both concrete and formal students in both classes. On a scale of 1 (strongly disagree) to 5 (strongly agree), after corrections for negative statements, the concrete operational students averaged 4.16 and the formal operational students averaged 4.26 when 3.0 was considered neutral.

TABLE 3. *Analysis of Variance for a 2 x 2 Factorial Design.*

Attitudes Measured After Instruction Segment One				
Source of Variance	SS	df	MS	F
Levels	86	1	86	1.15
Sequence	101	1	101	1.34
Levels x Sequence	116	1	116	1.54
Error	1803	24	75.1	
Attitudes Measured After Instruction Segment Two				
Source of Variation	SS	df	MS	F
Levels	3	1	3	0.04
Sequence	13	1	13	0.18
Levels x Sequence	56	1	56	0.75
Error	1781	24	74.2	

Parenthetically, a university-administered course evaluation indicated that those students in class one (concrete tasks first, followed by abstract tasks) rated the class as "outstanding" on 72% of the evaluations while those students in class two rated it as outstanding on 48% of the evaluations. It would appear that logical sequencing was at least partly responsible for this variation. For those students included in the study, attitudes measured on the first and the second administration of the study's attitude measure correlated .90. This could be used as a reliability coefficient, but it also indicates that attitudes did not appreciably fluctuate during the second half of the study. The only legitimate conclusion is that the concrete operational students, even though they achieved less, felt as good about the instruction as did the formal operational students.

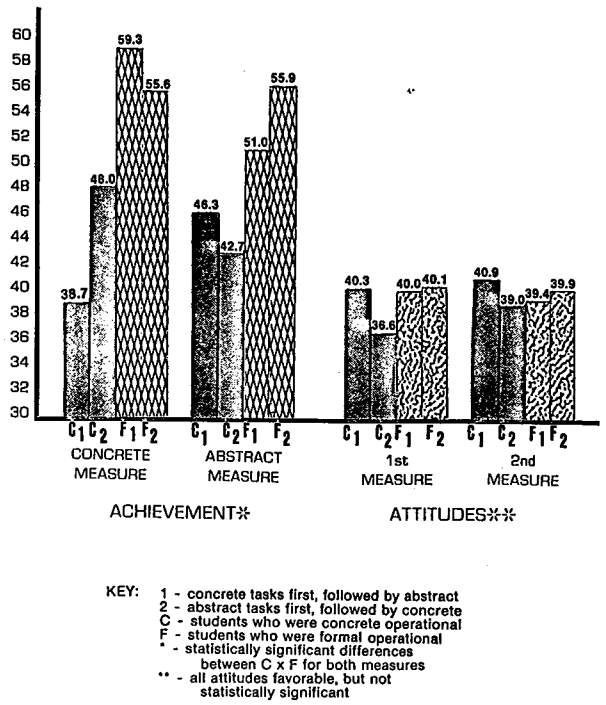
Discussion

In addition to the several limitations already mentioned, a cell size of seven is obviously small. Also, an individual Piagetian-type interview of each student might have been more efficient in identifying him/her more accurately as concrete or formal operational, although Burney's test is well documented for validity and reliability.

A thorough evaluation of concrete operational students, especially at the college level, holds great promise for improving instruction and meeting student needs. It has been assumed, at least at the theoretical level, that the abstractions present in most college instruction presents a "stacked deck" to the concrete operational student. The data from this study, although limited, do not support the notion because formal operational students achieved more even on simple concrete tasks where it might have logically been assumed that both groups would do equally well. Also, the abstractions involved in designing experiments did not cause any noticeable evidence of regression in the formal operational groups. They not only achieved more than the concrete operational students, but they also performed at a high level. Pre-learning experience in higher level process skills was not determined and could have been an influencing factor.

Any effort that considers the differing developmental levels of students and makes an honest effort to adapt instruction to meet individual needs should be encouraged. The obvious challenge is to assist as many as possible to reach formal thought as quickly as possible.

FIG. 1. *A Comparison of Preservice Teachers Identified As Concrete or Formal Operational.*



KEY: 1 - concrete tasks first, followed by abstract
2 - abstract tasks first, followed by concrete
C - students who were concrete operational
F - students who were formal operational
* - statistically significant differences between C x F for both measures
** - all attitudes favorable, but not statistically significant

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