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ABSTRACT

The research of Jean Piaget and his Genevan co-workers might lead one to believe that all adolescents are formal thinkers by the time they are 15 or 16 years of age. The studies reviewed by the author on formal thinking in the United States seem to support the contention that the majority of late adolescents and adults function at the concrete operational level and not at the formal operational level. The data collected and the conclusions arrived at by the researchers indicate that over 50 percent of the American population at age 16 and older function at the concrete operational level, thus contradicting Piaget's findings resulting from research with Genevan subjects. The discrepancy here is probably due to the subjects studied by Piaget. He appears to have chosen the more able students in his studies on formal thought development, hence finding greater cognitive development than he possibly would have found had he studied a truly random sample. If the cognitive development of late adolescents and adults has been accurately inferred from the studies cited, then it appears that many of our high school and college science courses are inappropriate. Since a great deal of the subject matter taught in high school and college science courses is geared toward formal thinking, these courses are not suited for concrete operational thinkers who probably represent the majority of students. It seems that curriculum developers need to develop science programs that are more geared toward concrete operational thinking than are the existing programs. (Author/BR)

A PERSPECTIVE ON FORMAL THOUGHT DEVELOPMENT

by

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A PERSPECTIVE ON FORMAL THOUGHT DEVELOPMENT

At first glance, the research of Jean Piaget and his Genevan co-workers might lead many educators to believe that most individuals are formal operational thinkers by 15 or 16 years of age. This may be a misconception on the part of many. Lovell (1961), who has performed many Piagetian studies with English students, discovered that some of the subjects used in his studies were not formal operational thinkers by the age of 15. He has stated that he suspected the subjects with whom Piaget worked in Geneva were rather able students, thus providing Piaget with adolescents who at 15 and 16 years of age were demonstrating formal reasoning. Higgins-Trenk and Gaite (1971) concluded from their study on formal operations with American subjects "that normal adolescents are unlikely to reach the level of formal thinking until their late teens or early twenties if they reach it at all."

An analysis of studies on formal thought development in the United States has led to the generalization that the majority of adolescents and adults function at the concrete operational level and not at the formal operational level when having to deal with abstract science materials. In some samples it was determined that only 14 percent of the individuals were capable of formal reasoning, while in other samples it was determined that 78 percent of the individuals were capable of formal reasoning. It was determined that the percentage of individuals at the concrete operational level ranged from 22 to 66 percent. Furthermore, the percentage of individuals who function at the concrete operational level appears to increase when learning science is involved. The assertion set forth in this paper is that one half or more of the individuals classified as formal operational function at the concrete operational level when they are tested on science content requiring formal reasoning for its full understanding.

If the above assertion is correct, then it appears that many of our high school and college science courses are inappropriate. College and high school science courses deal with formulas, rules, laws, hypotheses, relationships, theories, etc. all of which

require formal reasoning for their complete understanding. Individuals who function at the concrete operational level when confronted with this type of subject matter will only memorize facts and relationships and solve problems by mechanically plugging into formulas. Such a learning strategy leads to very little understanding and retention of the material being taught.

There is a great difference between the thinking ability of the concrete and formal operational thinkers. The formal operational thinker can "look at" ideas, objects, and events from a variety of view points. He can look at a total system and see the relationships among its parts. The concrete operational thinker views a total system from a limited perspective, enabling him to see only a limited number and type of relationships among its parts. He can order objects and events as well as classify and add them together--only if the objects and events are in view or are very familiar to him. The individual at the concrete operational stage can perform only basic logical operations, while the formal operational individual can perform operations upon basic logical operations, thus enabling him to employ hypothetical-deductive reasoning, which for the most part is unavailable to the concrete operational thinker.

RESEARCH ON FORMAL OPERATIONS

The studies reviewed in this section pertain to research on formal operational thinking with American subjects. They comprise all of the studies which could be found in the literature and elsewhere based on the following criteria: (1) all or part of the sample consisted of subjects 16 years of age or older, (2) the tasks employed to assess developmental level were similar to those used by Piaget in assessing cognitive development, and (3) the percentage of formal operational thinkers was either reported or could be determined from the data given.

McKinnon and Renner (1971) questioned whether the majority of college freshmen were mentally prepared to adequately deal with many science principles taught at the college

level. While they recognized that Piaget had determined with Swiss students that formal thinking develops between the ages of 11 and 15, they hypothesized that most American high school graduates were not at the formal operational level. McKinnon and Renner used five tasks designed by Piaget (Inhelder and Piaget, 1958) and found that approximately 50 percent of the college freshmen in their sample were concrete operational thinkers, 25 percent were in transition to formal operational thinking, and only 25 percent could be clearly classified as formal operational thinkers.

Higgins-Trenk and Gaite (1971) studied formal thinking in a sample of 162 junior and senior high school students in a Wisconsin secondary school. The students were divided into four groups as follows: Group 1 (mean age 13.4), Group 2 (mean age 14.7), Group 3 (mean age 15.7), and Group 4 (mean age 17.7). Higgins-Trenk and Gaite reported that on the Piagetian conservation of volume task 43 percent of the students operated at the formal operational level, while on a situational problem only 32 percent operated at the formal operational level. When the approximately 40--Group 4--subjects are considered, it was reported that over 50 percent of the students did not score at the formal operational level on either of the two tasks used. Higgins-Trenk and Gaite concluded their study by saying "that normal adolescents are unlikely to achieve formal thinking by their late teens or even early twenties if they reach it at all."

Tomlinson-Keasey (1972) investigated the developmental level of females from 11 to 54 years of age. A total of 89 subjects participated in the study, consisting of sixth-grade girls (mean age 11.9), college coeds (mean age 19.7), and women (mean age 54). The Pendulum, Balance, and Flexibility Tasks were given to the subjects to measure the developmental level. The results indicate that 32 percent of the girls were rated at the formal operational level, 67 percent of the coeds were at the formal operational level, and 54 percent of the women were at the formal operational level. Tomlinson-Keasey pointed out in her research that the formal operational level of cognitive development, unlike the concrete operational level, "represents a potential

to be reached rather than an assured stage of development."

Renner and Stafford (1972) assessed the developmental level of 588 students in grades 7 - 12 over the entire state of Oklahoma. They used six Piagetian tasks to assess the developmental level of the students. Their results show that of the 290 students in grades 10, 11, and 12 three percent were pre-operational, 66 percent were concrete operational, 17 percent were post-concrete operational, and 14 percent were formal operational. The majority of adolescents in their sample were at the concrete operational level.

Renner and Stafford (1972) also studied the logical thinking of law students. They randomly selected a total of 44 first and third year law students to interview. On the Piagetian elimination of contradiction tasks, 86 percent of the subjects were rated formal operational, while 14 percent were rated concrete operational. On the exclusion of variable tasks, 70 percent were rated formal operational, while 30 percent were rated concrete operational. A large percentage of the adults appeared to be at the formal operational level as might be expected with a highly select sample of professional students.

Lengel and Buell (1972) used the Pendulum Task to study the logical operation of exclusion. They randomly selected 20 lower SE science students in grades 7, 9, and 12. Their results show that 45 percent of the seventh graders were at the formal operational level while 55 percent were at the concrete operational level, 40 percent of the ninth graders were at the formal operational level while 20 percent were at the concrete operational level, and 85 percent of the twelfth graders were at the formal operational level while 15 percent were at the concrete operational level. Since only one Piagetian task was used in the study, there is some question as to the adequacy of Lengel's and Buell's results for assessing overall cognitive development.

Coleman (1973) studied the effects of age on the cognition of women. The sample used in her study consisted of 100 middle class caucasion females ranging in age from 20 to 94 years. Two sub-groups with a mean age of 33.9 years and 54.9 years comprised what was referred to as the younger group of women, while the two sub-groups with a mean age of 74.4 and 84.5 years were referred to as the older group of women. The women were given conservation tasks (mass, weight, and volume), a logic task, and a combinational task. Coleman reported that on the text of logic more than 50 percent of the younger group scored at or below the level of concrete operations. She concluded that aging women largely function at the concrete level with some evidence of regression toward the pre-operational level.

Lawson (1974) analyzed the relationship between concrete and formal operational science subject matter and the developmental level of the learner. He selcted 51 bilology, 50 chemistry, and 33 physics students from a high school in Norman, Oklahoma. Six Piagetian type tasks were administered to each subject. Lawson categorized the subjects into the following seven groups: concrete IIA, transition concrete, concrete IIB, post-concrete, formal IIIA, transition formal, and formal IIIB. His data has been grouped and is reported for the purpose of this paper in two categories--conrete and formal operational. Entries in the categories of concrete IIA, transition concrete, concrete IIB, and post-concrete will be reported as concrete operational. Entries in the categories formal IIIA, transition formal, and formal IIIB will be reported as formal operational. Lawson's results show that 64.8 percent of the biology students appeared to be at the concrete operational level, while 35.2 percent appeared to be at the formal operational level; of the chemistry students, 22 percent appeared to be at the concrete operational level while 78 percent appeared to be at the formal operational level. Of the physics students, 36.3 percent appeared to be at the concrete operational level while 63.7 percent appeared to be at the formal operational level.

Chiappetta (1974) investigated the relationship between proportional thought development and physical science achievement. He administered the Balance Task to 15 K-8 female teachers in Houston, Texas. It was found that 47 percent of the subjects were at the formal operational level and 53 percent were at the concrete operational level in respect to their proportional reasoning ability.

Chiappetta and Whitfield (1974) investigated the cognitive development of high school seniors. They selected 26 seniors from three academic tracks--vocational, general, and college preparatory--in a high school in a suburb of Houston, Texas. Three tasks were given to each student to assess the developmental level. They included the Balance Task, the Chemical Combination Task, and the Volume Task. In the vocational student group, 61.5 percent were at the concrete operational level while 38.5 percent were at the formal operational level. In the general track group, 53.8 percent were at the concrete operational level while 46.2 percent were at the formal operational level. In the college preparatory program, 27 percent were at the concrete operational level while 73 percent were at the formal operational level.

The summary of the studies reviewed are presented in Table 1.

If the studies that used two or more Piagetian tasks to measure cognitive development are considered, it is apparent that the percentage of individuals at the formal operational level ranges from 14 to 78 percent. Likewise, the percentage of individuals at the concrete operational level ranges from 22 to 66 percent. The data indicate that most (over 85 percent) adults and adolescents are <u>not</u> at the formal operational level as measured by Piagetian tasks.

A CASE FOR ASSERTING THAT MANY INDIVIDUALS CLASSIFIED AS FORMAL OPERATIONAL FUNCTION AT THE CONCRETE OPERATIONAL LEVEL IN SCIENCE

Research concerning the relationship between cognitive development and science achievement at the adolescent and adult levels is just beginning to appear in the literature. An analysis of a few such research studies suggests that one half or more of individuals classified as formal operational appear to function at the concrete operational level when tested on science subject matters requiring formal reasoning for its complete understanding. This apparent regression to a lower level of intellectual functioning may partially be explained in terms of assessment. Classifying individuals as functioning at a particular developmental level can lead to erroneous expectations on achievement in science courses.

The results of Lawson's (1974) study show the "regression effect" demonstrated by students classified as formal operational when tested on formal science concepts. Although the formal operational subjects understood significantly more formal concepts than the concrete operational subjects, they did not master full understanding of the majority of formal concepts on which they were tested. The formal operational thinkers demonstrated a great deal more understanding of concrete concepts than of formal concepts in science.

Lawson selected 51 biology, 50 chemistry, and 33 physics students from a high school in Norman, Oklahoma, for the study. He administered six Piagetian type tasks to the subjects to determine their developmental level. Subjects were classified as: concrete substage IIA, transition concrete, concrete substage IIB, post concrete, formal substage IIIA, transition formal, and formal substage IIIB. Subject matter tests were given to the subjects in their respective disciplines following the administration of the Piagetian tasks. The tests consisted of two parts. One part was a 15-item

multiple choice test involving concrete operational science concepts, while the other part was a 15-item multiple choice test involving formal operational science concepts.

Figure 1 shows an overall comparision of the achievement of the biology, chemistry, and physics students at various developmental levels on concrete and formal test questions. The figure shows that the formal IIIA, transitional formal, and the formal IIIB subjects achieved correct answers on approximately 20 percent, 38 percent, and 43 percent of the formal concepts respectively, while they achieved correct answers on approximately 62 percent, 70 percent, and 82 percent of the concrete concepts respectively. This data seems to indicate that formal operational thinkers achieve full understanding on less than half of the formal concepts on which they are tested.

Chiappetta's (1974) study also shows the "regression effect" demonstrated by individuals classified as formal operational in reference to their proportional thought development. A large percentage of individuals rated at the formal operational level appeared to function at the concrete operational level when tested on their full understanding of physical science topics. They solved physical science problems correctly by plugging into mathematical formulas, but they could not give simple examples to analogize the underlying principles involved.

The study involved 15 K-8 female teachers who were participating in an NSF supported Up-Step summer institute at the University of Houston, Houston, Texas. The teachers were presented with the Balance Task (Inhelder and Piaget, 1958) to assess their proportional thought development. They were rated low concrete (IIA), high concrete (IIB), low formal (IIIA), or high formal (IIIB) as a result of their performance on the Balance Task.

The subjects participated in a highly self-paced laboratory physical science course following their exposure to the Balance Task. The term "highly self-paced" is defined by the fact that subjects were told that they would be evaluated on how well they understood whatever it was they were able to cover in the course not how much they covered.

At the end of each laboratory unit completed, each subject was given a paper and pencil test to complete which was followed by an interview with a physics instructor. The subject was questioned to determine how well she understood the items on the test. The criteria which were used to assess overall physical science achievement and their corresponding numerical values are given as follows:

1--The individual required many hints from an instructor to complete the unit exams correctly. She could not accurately explain how the answers were arrived at. Also, she could not give simple examples of the problems that were correctly solved.

2--The individual could complete about 75 percent of each unit exam correctly and could complete the rest of each exam correctly with hints from an instructor. She could not accurately explain how the answers were arrived at nor could she give a simple example of the problems that were correctly solved.

3--The individual could complete approximately 100 percent of the unit exams correctly except for trivial arithmetic mistakes. She could accurately explain most of the answers and could give simple examples of the problems that were correctly solved.

A bivariate frequency distribution for teacher rating on the Balance Task and overall physical science units is presented in Figure 2. Inspection of this figure indicates that subjects rated as being formal operational in their proportional thought development achieved higher scores in physical science achievement than subjects rated as being concrete operational. Although the formal operational subjects (IIIA and IIIB) scored higher than the concrete operational subjects, not all of them achieved full understanding of the physical science concepts taught. About half, or 43 percent, of the formal operational subjects were rated a two in the course, indicating they

could complete about 75 percent of the written exams correctly but could not accurately explain how the answers were arrived at. Nor could they give simple examples of the problems that were correctly solved on paper.

A bivariate frequency distribution for teacher rating on the Balance Task and achievement on a unit pertaining to solubility is represented in Figure 3. The information in this figure shows that, of the subjects who were rated as being formal operational in respect to proportional thought development, about 71 percent of them did not achieve complete understanding of the material they studied on the topic of chemical solubility. The solubility laboratory unit primarily dealt with ratios and proportions making it an ideal situation in which to study the relationship between developmental level and the understanding of a science topic with respect to a particular intellectual schema.

In the two studies analyzed above, evidence indicated that one half or more of the individuals classified as formal operational appeared to function at the concrete operational level when dealing with abstract science material. This apparent regression to a lower level of cognition can be explained by a combination of several factors, e.g., aptitude, interest, background knowledge, and instruction. However, from a developmental sense, one factor can be identified that might explain the "regression effect," namely that of assessment.

Individuals are not always at the same stage of development in regard to different substantive areas. For example, a person can demonstrate formal reasoning on tasks involving proportions and the isolation of variables. The person can demonstrate concrete reasoning on tasks involving combinations. Such an individual may be rated at the formal operational level because he demonstrated formal reasoning on two of three tasks. He will probably demonstrate concrete operational reasoning on a problem requiring combinational thinking for its solution. Hence, assessing the cognitive development of individuals to particular stages can be misleading.

DISCUSSION

Formal thought development was considered from two aspects. The first was from the performance of individuals on Piagetian tasks, which yielded the conclusion that most (over 85 percent) Americans 16 years of age and older do not appear to be at the formal operational level. The second aspect was from the achievement of formal operational individuals in science, which asserted that many (a majority or more) potentially formal operational thinkers appear to function at the concrete operational level when tested for their understanding of science material requiring formal reasoning for its full understanding. Hence, when it comes to abstract science content, the majority of adolescents and adults appear to function at the concrete operational level.

Of paramount significance is the implication that this has on science teaching. First, it seems that high school and college science courses are somewhat inappropriate for the majority of people. The courses contain a great deal of subject matter which is abstract in nature, such as relational concepts, proportions, laws, and theories. This type of material required formal reasoning for its complete understanding. Hence, they are inappropriate for individuals who function at the concrete operational level.

Second, research needs to be conducted to determine which inquiry skill, as well as science content, require formal and concrete operational reasoning for their understanding or use. Concepts, principles, laws, theories, etc. taught in the biological and physical sciences along with inquiry skills such as classifying, hypothesizing, controlling variables, and experimenting can be analyzed. This type of information, along with a thorough knowledge of assessing developmental levels, will give science education more useful information upon which to base their teaching.

TABLE I

PERCENTAGES OF SUBJECTS AT VARIOUS DEVELOPMENTAL LEVELS

STUDY			DEVELOPMENTAL LEVEL		
Researcher	Sample	Number of Tasks used	Concrete %	Transitional %	Formal %
McKinnon and Renner (1971)	131 college freshmen	5	50	25	25
Higgins-Trenk and Gaite (1971)	162 students grades 7-12	1	57*	-	43
		1	68*	-	32
	40 students mean ages 17.7 yrs.	2	50+	-	-
Tomlinson-Keasey (1972)	89 females mean ages	3			
	11.9 yrs.		68*	-	32
	19.7 yrs.		33*	-	67
	54 years		46*	-	54
Renner and Stafford (1972)	290 students grades 10, 11, 12	6	66	17	14
Renner and Stafford (1972)	44 law students	1	14	-	86
		1	30	-	70
Lengel and Buell (1972)	secondary students	1			
	20 grade 7		55	-	45
	20 grade 9		20	-	40
	20 grade 12		15	-	85
Coleman (1973)	100 females mean ages				
	33.9 & 54.9 yrs.	1	50+	-	-
	74.4 & 84.5 yrs.	-	-	-	-
Chiappetta (1974)	15 K-8 female teachers	1	53	-	47
Lawson (1974)	high school students	5			
	51 biology		64.8	-	35.2
	50 chemistry		22	-	78
	33 physics		36.3	-	63.7
Chiappetta and Whitfield (1974)	high school seniors	3			
	26 vocational		61.5	-	38.5
	26 general		53.8	-	46.2
	26 college prep.		27	-	73

*Percentages not reported in the study per se but calculated from the data given.

FIGURE 1

A COMPARISON OF SUCCESS ON CONCRETE AND FORMAL CONCEPTS
WITH CHANCE ELIMINATED-POOLED DATA

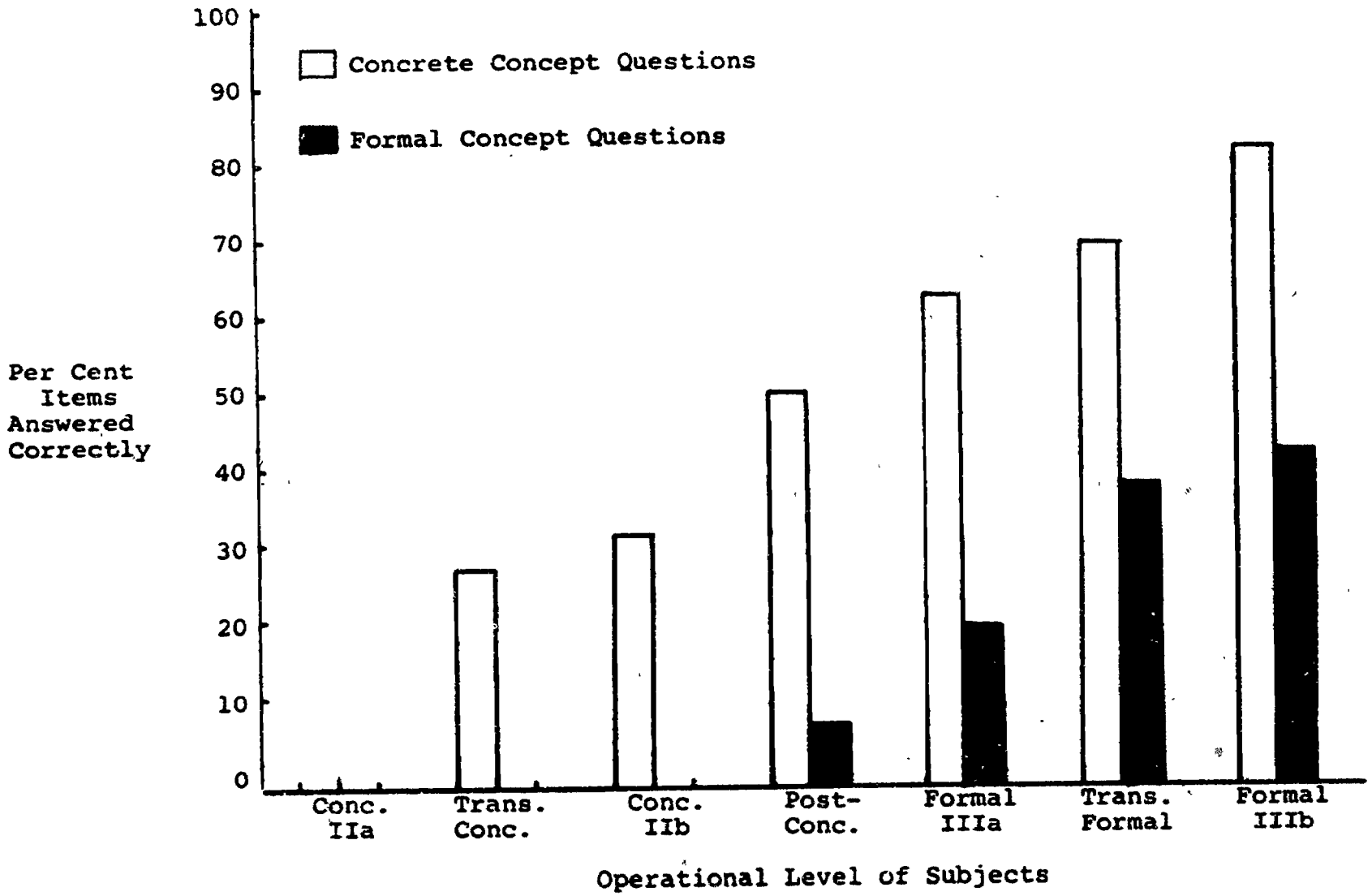


FIGURE 2

BIVARIATE FREQUENCY DISTRIBUTION FOR BALANCE TASK AND OVERALL PHYSICAL SCIENCE UNITS

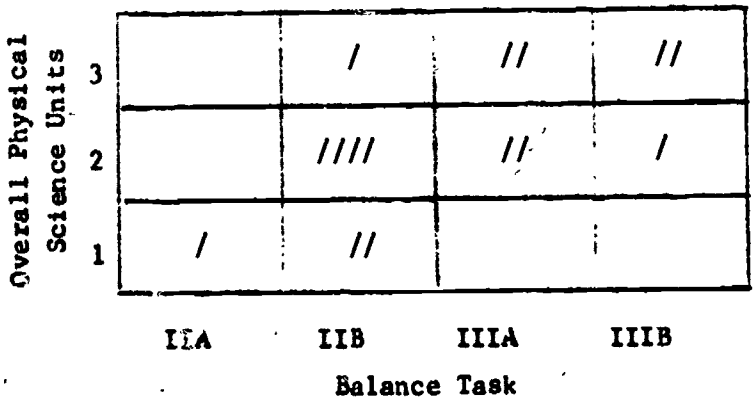
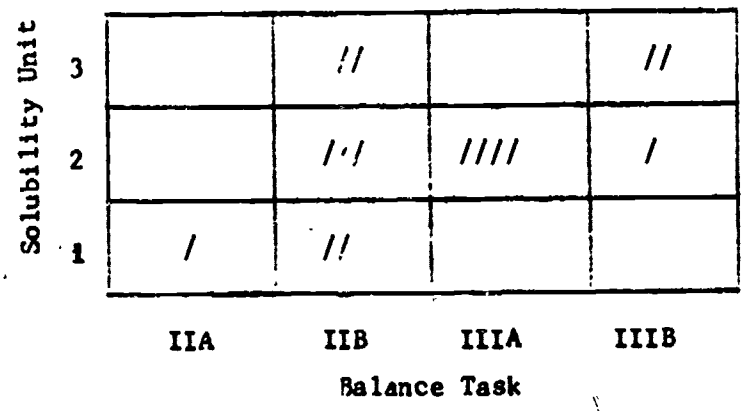


FIGURE 3

BIVARIATE FREQUENCY DISTRIBUTION FOR BALANCE TASK AND SOLUBILITY UNIT



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