

PIAGETIAN THEORY AND ABSTRACT PREFERENCES OF COLLEGE STUDENTS
TAKING GENERAL PHYSICS I

by

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Chapter 1

INTRODUCTION

A review of the literature published over the last decade related to science education shows a steady increase in the number of articles about the developmental psychology of Jean Piaget applied to science education and curriculum development. Though Piaget's comprehensive work spans nearly sixty years it has not been but until the last twenty years that his ideas have gained popularity with science educators in America. The replication of Piaget's clinical methods for evaluating cognitive development has revealed expected similarities and a number of differences to Piaget's results. Whereas the similarities help in confirming his theory of mental development, the differences raise a number of questions which need to be thoroughly studied before conclusions can be drawn.

One deviation in particular, according to several studies (McKinnon and Renner, 1971; Lawson, 1974; Chiappetta and Whitefield, 1974) with first-year college freshmen in America, about forty percent are not functioning at the "formal" level as predicted by Piaget's theory. His model of cognitive development indicates that a significantly large percentage of students in that age group should be functioning at the formal level. This result, alone, has caused concern to educators as to why this is so. And, what does this tell us about our present-day curriculum practices in science education?

One theory that has been suggested to explain these results (Dunlop and Fazio, 1976; Raven, 1974) supports the contention that a student's level of reasoning is often below his capacity. Furthermore, despite his cognitive level of reasoning, it is his "abstract preferences" toward a problem situation that may determine what method he will select to solve the problem. Another theory has been suggested (Fuller, 1977; Lawson, 1976; et al.) that the level of formal reasoning has been stifled from the lack of adequate concrete experiences. In an indirect response to the latter theory has stemmed a strong effort to develop other devices hypothesised to measure cognitive abilities (Lawson, 1978; Barns, 1977, 1978) that are in a pencil-and-paper form. In Piaget's interviews all information was obtained from observing and listening to individuals as they manipulated actual materials (Piaget, Inhelder, 1958).

Based on these, and other studies, one becomes aware of the somewhat conflicting, if not confusing, results in the application of Piaget's theory toward cognitive development.

STATEMENT OF THE PROBLEM

This investigation addresses itself to the following questions:

- (1) Can instructional procedures and active participation in an introductory college physics course successfully affect the transition from concrete to formal cognitive functioning as described by Jean Piaget?
- (2) Can instructional procedures and active participation in an introductory college physics course successfully affect the transition of a student's abstract preferences in problem

solving from concrete to formal approaches as shown by the abstract preference survey?

- (3) Could abstract preference be another factor which might influence one's choice of approach when faced with a problem situation other than cognitive ability?

HYPOTHESES

The hypotheses expressed in null form are as follows:

- H_1 : There is no significant difference between the subject's pre-test and post-test performance on selected Piagetian-type tasks as indicated by their mean scores.
- H_2 : There is no significant difference between the subject's pre-test and post-test performance on the abstract preference survey as indicated by their mean differences.
- H_3 : There is no significant difference between a student's abstract preferences and his level of cognitive development.

OPERATIONAL DEFINITIONS

1. Cognitive levels--Piagetian theory postulates stages of mental development based on observable characteristics. Though mental development does not proceed in jumps and steps but rather proceeds as a gradual progression. Piaget draws a line distinction at certain points based on differentiating characteristics and labels them as levels or stages of cognitive development. Piaget recognizes four such levels.

2. Assimilation--The process of changing elements in the milieu in such a way that they can become incorporated into the structure of

the organism; i.e. the elements are assimilated to the system.

3. Accomodation--Through various interactions taking place over some period of time the individual develops a balance between similar situations and necessary mental operations to handle them.

4. Adaption--An act of intelligence in which assimilation and accommodation are in balance with each other.

5. Operations--A means for mentally transforming data and concepts about the real world so that they can be organized and used selectively in the solution of a problem and in understanding new concepts.

6. Concrete operational--The third level of cognitive development in Piaget's model. The individual at this level focuses on that which is immediate and real and not to that which is possible. Concrete reasoning emerges at about the age of seven and develops toward the next level.

7. Formal operational--The fourth and highest level of cognitive development postulated by Piaget. The individual at this level of reasoning is less restricted by that which is empirically real and sees it as simply a special case of that which is possible. Formal reasoning follows the development of concrete reasoning.

8. IIA, IIB, IIIA, IIIB--Symbolizes the concrete and formal levels of cognitive development: IIA, early concrete; IIB, late concrete; IIIA, early formal; IIIB, late formal. This notation is used for simplification and clarity.

9. Self-regulation--An active process of forming new reasoning patterns that integrate new concepts and/or resolve apparent contradictions perceived in the framework of old reasoning patterns.

10. Abstract preferences--Based on the Piagetian construct of mental development, that mental operation the individual initiates in a problem situation signifies his abstract preference. The preference is identified as being either concrete or formal.

LIMITATIONS OF THE STUDY

A number of limitations to this investigation are as follows:

- (1) A larger number of subjects would have been preferred.
- (2) Two or three more Piagetian-type tasks was desired but time limitations and the use of only one interviewer prevented it.
- (3) The preference survey developed by the author may still lack complete construct validity or reliability, thus farther evaluation of the instrument might be necessary.

Chapter 2

REVIEW OF THE LITERATURE

Though the work of Jean Piaget spans more than five decades it has not been but until recently that his work has been applied by science curriculum developers and teachers alike. Not to be confused with developing another method of teaching, Piaget and his co-workers have developed an elaborate theory about mental development. Through the testing of children of various ages it has been found that certain mental operations and concepts appear at certain points of development of an individual's life (Inhelder and Piaget, 1958). Moreover, it has been shown that the appearance of these concepts and operations proceed in the same order for each person, though not at exactly the same rate.

The basic foundation of Piaget's theory of mental development is what he calls the assimilation/accommodation process (Piaget and Inhelder, 1958). Flavell (1977) provides an illustrative example of how this mental process works and leads to mental development. Consider a small child playing in the bathtub with an assortment of toyboats. To the child these toys represent a subclass of the realm of boats. That is, he mentally assigns certain properties to the toys that are characteristic to real boats: floating, bobbing, shape, etc. Now the child notices a small wooden stick beside the tub and proceeds to place the object into the tub of water. To his surprise, he discovers that it, too, floats like his toy boats. Upon playing with this stick he also notices that it demon-

strates some of the toy boat's properties and mentally assimilates those matching properties to the stick. It is then mentally added as another subclass of boats. At the same time he recognizes the differences the stick has to his boats, i.e. he accommodates the new object in light of those properties which define a real boat. To the child the stick can be played with as a toy boat but is still recognized as a wooden stick. Through his actions the child has expanded his mental operations and concepts about toy boats to include the stick.

This process has its limitations, however. Piaget observed that certain mental processes appear at certain ages (Inhelder and Piaget, 1958) prior to which were absent. Though assimilation and accommodation process may be taking place it is not until the two are in equilibrium with each other that the concept or operation is adapted and therefore begins to appear. It is through a number of interactions with the related milieu that the unstable mental balance develops toward one of stability.

Piaget's theory postulates four stages of mental development through which all individuals proceed toward a higher cognitive form of reasoning (Inhelder and Piaget, 1958). Piaget established these stages mainly for communication purposes while today they have been given more of a distinction by others continuing his work. His theory does not try to explain how various mental structures are formed, but he has outlined certain basic mental operations that dictate one's behavior from birth on into adulthood. It is important to point out that according to the theory each advancement in mental development is built upon previously adapted mental structures, operations, and concepts.

Three variables have been identified by Piaget (1958) as being those which contribute to cognitive development: experience acquired from the environment, maturation of the nervous system, and the social milieu. Through the active process of self-regulation the individual builds and modifies mental structures until they become internalized as knowledge which, in turn, control how and what one thinks and guides one's behavior.

Of the four stages modeled by Piaget (sensory-motor, preoperational, concret operational, and formal operational) the last two will be examined in this investigation. At about the age of seven the child begins to demonstrate concrete operational thought. This level of mental development allows the child to perform mental operations (e.g. reversal thinking, class exclusion, grouping, and organizing heierarchy (Flavell, 1963)). Between the ages of eleven to fifteen the adolescent begins to demonstrate formal operational thinking. This stage is characterized by the individual's ability to think beyond the present or that which is real. Formal operational thinking can be characterized as reasoning with propositions only and has no real need for objects, it is the case with the concrete thinker (Flavell, 1963). Below are other characteristics found in each stage. (Fuller, Karplus, and Lawson, 1977).

CONCRETE OPERATIONAL

1. Needs reference to familiar actions, objects, and observable properties
2. Uses classification, conservation, serial ordering and one-to-one correspondence in relation to real objects.
3. Needs step-by-step instructions.
4. Investigates the effects of one variable without holding all others constant.

5. Responds to different situations by applying a related but not necessarily correct algorithm.
6. Fails to see all sources of error, does not check his conclusions against a given data or other related experience.
7. Begins solving a problem by starting with real objects in action.
8. Uses limited combinational reasoning, fails to recognize all possible combinations.

FORMAL OPERATIONAL

1. Controls variables to validate results.
2. Able to use classification based on various properties and does not concentrate on a single one.
3. Uses classification and exclusion based on abstract properties.
4. Uses probabilistic correlations.
5. Can take an unproven hypothesis and deduce consequences in light of other information.
6. Recognizes the dependence between variables, and states the relationship in mathematical form or symbolic form.

J. H. Flavell (1963) provides an excellent description contrasting the two levels of thought.

The child of concrete operations can be caricatured as a sober and bookkeeperish organizer of the real and a distruster of the subtle, the elusive, and the hypothetical. The adolescent has something of both: the 7-11-year-old's zeal for order and pattern coupled with a much more sophisticated version of the younger child's conceptual daring and uninhibitedness. Unlike the concrete-operational child, he can soar; but also unlike the pre-operational child, it is a controlled and planned soaring, solidly grounded in a bedrock of careful analysis and painstaking accommodation to detail.

For Piaget, formal thought is more of an orientation rather than a specific behavior towards problem solving (Flavell, 1963). Whereas the concrete thinker starts with that which is empirically real do deduce

further propositions, the formal thinker starts with the possible. For the formal thinker reality is conceived as a special subset within the realm of that which is possible. Furthermore, the formal thinker is less restricted when presented new concepts as compared to the concrete thinker.

The question that has been raised by many learning psychologists is how can formal-operational thought be promoted (Fuller, Karplus, Lawson, Renner, Dystra, et al.)? According to Flavell (1963) Piaget suggests that the subject moves from concrete-operational thinking to formal-operational thinking much the same way to which the transitions to the previous stages was affected. Piaget (1958) explains that transition is made possible when the individual's concrete operations are no longer adequate to function with the tasks faced by the adolescent. He states that, "the equilibrium attained by concrete thought covers only a relatively narrow field". These two circumstances make the elaboration of formal thought "necessary" (Inhelder and Piaget, 1958).

Studies by Lawson and Wollman (1976) and Renner and Lawson (1973) contend that, based on the many studies that have shown a large percentage of adolescents do not use formal-operational thought reliably, transition can be promoted by providing the proper settings. These settings include inquiry-type situations with an adequate number of concrete experiences. It is further contended by Fuller, Lawson, and Karplus (1977) that physics can be natural medium through which formal thought can be encouraged. The contributions science may have to offer to encourage the transition to formal thought is still in its early stages of understanding. This is shown by the increasing number of related articles and research projects being reported.

There should be some degree of caution taken, however, with the implications of the early results. David Ausubel (1964) states that, "if stages of development have any true meaning, the answer to this question can only be that although some acceleration is possible, it is necessarily limited in extent". In a study conducted by John Renner and William Paske (1975) at the University of Oklahoma, students taking beginning physics had the opportunity of selecting the type of instruction they would prefer, i.e. a concrete approach or a formal approach. At the end of their study they measured the possible changes in cognitive development that might have occurred. The total percentage of students that made a positive change under the formal mode of teaching was 37.6% while those under the concrete mode of instruction showed a 43.2% positive change. It must be pointed out, however, that in that same study about 20% of the students under the concrete instruction showed a negative change! It should be noted that the instrument used to measure cognitive development was not the same as that originally used by Piaget but rather was a pencil-and-paper type instrument developed by those authors. The results, therefore, may not be totally conclusive, however, they should not be disregarded. Since pencil-and-paper type questions are commonplace in education, their role may be taken for granted in light of Piaget's model.

Piaget strongly suggests the need for concrete experiences in order for formal thought to develop (Inhelder and Piaget, 1958; Ausubel, 1964). When we look at the results of careful studies made here in the United States it appears that while almost all of us reach concrete-operational thought, not all of us demonstrate formal-operational thought reliably! Consider the table of results in part as was compiled by Frank Fazio and David Dunlop (1976):

Table 1

Researcher	Developmental level	Sample
McKinnon and Renner (1971)	50% concrete 25% transitional 25% formal	131 college freshman
Lawson (1974) using high school students	64.8% concrete 35.2% formal	51 biology students
	22% concrete 88% formal	50 chemistry students
	36.3% concrete 63.7% formal	33 physics students
Chiappetta (1974) using 15 K-12 female teachers	53% concrete 47% formal	

These results have been the basis for further studies concerning our present practices in education, particularly in the sciences. At the college level, where abstract concepts are ubiquitous, such results have strong implications. In response to these findings some universities have included in their course selection of physics one which offers the student a concrete approach as opposed to the traditional abstract approach. Individuals who further support this curriculum modification are Fuller, Karplus, and Lawson (1977), Ausubel (1968), and Bauman (1976). Though much investigation is going on as to the contributions the study of science may have to cognitive development, it is still not fully understood what the contributions are (Lawson and Wollman, 1976).

An interesting contention is made by Ronald Raven (1974) and consequently by Fazio and Dunlop (1976) that the level of reasoning used by an individual when solving problems may be substantially below his capacity. In the case of Raven second grade subjects were given training

in logical operations skills. The instructional strategy he used required the students to solve problems involving logical operations after they had been shown how similar problems could be solved. The findings of his studies indicate that the use of structured training materials "was found to enhance the achievement of pupils on logical operations tasks".

Frank Fazio and David Dunlop (1976), in order to test the assumption that the level of reasoning used by students in problem solving may be substantially below their cognitive ability, have developed an instrument which required the subjects to select a particular method for solving a hypothetical problem. The validity of their instrument was based on the Piagetian construct which assumes a strong concrete preference thinker tends to start the solving of the problem with objects in action as opposed to the abstract preference thinker who would initiate deductive reasoning and mental manipulation. To test their hypothesis they administered to four hundred sixty-six college freshmen the Shipley Test for Abstract Reasoning to group the subjects into the two major groups of concrete and formal operational (Shipley, 1940). The subjects were then given the Abstract Preference Survey.

The results from this study showed that there was no significant difference between the science majors' and the non-science majors' cognitive abilities while their abstract preferences were significantly different. Their study failed to show any correlation for either group between their cognitive abilities and their abstract preferences. Fazio and Dunlop (1976) contend, based on their study results, that "science and non-science majors demonstrate different problem-solving preferences, but not different cognitive abilities".

In a follow-up study by Dunlop and Fazio (1979) one hundred sixteen science students with ages ranging from fifteen to twenty-two were given the Abstract Preference Survey. Several days later the same subjects were interviewed and given the opportunity to actually solve three of the problems. All of the students were also given the Shipley Test of Abstract Reasoning to determine the student's level of reasoning. The results from this investigation showed that the "student's preferences that indicate a preferred method for solving a hypothetical problem may quickly change when the problem becomes real". Furthermore, their results indicate that the change, being one direction or the other, is task dependent. Students with high abstract ability may prefer an abstract approach to a particular problem while preferring a concrete approach to another.

When examining the percentages of concrete and formal operational students that attempted and successfully completed the task they indicated on the preference survey, their results indicated that "although several concrete students preferred to solve the problems in an abstract manner, they were unsuccessful in their efforts. However, when examining the success for those who preferred to use the concrete approach, one may see that the concrete students were almost as successful as the formal students".

Because of the interview nature of Piaget's evaluative process, which is time-consuming and difficult to administer, there is a definite movement toward a more convenient method. The most prevalent type of test is some form of pencil and paper test (Renner, 1977). In contrast to the Piagetian method of presenting to the individual objects to

manipulate the pencil and paper form presents hypothetical problems. One of the latest forms developed by Lawson (1978) incorporates a demonstration for each item. David Maloney (1981) responds to these pencil and paper type tests by raising the question, "How can I be sure that the new procedure is accurately measuring Piagetian level?". He cites one example developed by G. Barns (1977) where a particular question was examined and in the words of Maloney he concludes that "these results clearly show that the (Barn's) letter puzzle, whatever it is measuring, is not correlated to Piagetian levels of reasoning". He further contends, "Even tasks which at first seem to discriminate quite well, i.e. the Islands Puzzle, can be measuring an ability unrelated to Piagetian level".

The general theory of Jean Piaget and the other studies cited in this review of the literature provides the basis for the following investigation. It is the intention of the author to gain some insight about what may be conflicting, if not confusing, results of the other studies in light of the Piagetian construct and problem solving practices.

Chapter 3

METHOD

SUBJECTS

The subjects (Ss) selected for this study were thirty-two students all currently enrolled in General Physics I. All Ss were volunteers for this investigation. The choice of this particular course as opposed to the other possible courses offered by the department of physics was based on several factors which were considered both unique and advantageous to the study.

General Physics I is a required course for pre-veterinarian, pre-medical, pre-dental, construction science, and geology students. Most students elect to take the course during their sophomore or junior year while a few may enroll in their freshman or senior year. Because this course is prerequisite to those courses of advanced study, above average grades are considered helpful (if not necessary) in getting accepted into them. Therefore, it is not uncommon for students to put extra effort into this course in order to be competitive for the higher grades.

EXPERIMENTAL DESIGN

The experimental design used for this investigation is described in Campbell and Stanley's Experimental and Quasi-Experimental Designs for Research (1966) as the "separate-sample pre-test-post-test design. Given

in the following form:

$$\begin{array}{cccc} R_1 & O_1 & X & O_2 \\ R_2 & & X & O_3 \end{array}$$

where R is the random selected population, X is the treatment (General Physics I in this case), while the O 's represent the variable being tested at that time. The design is not inherently a strong one but is superior to the ordinary before-and-after design in that it controls for both the main effect of testing and the interaction of testing with the treatment, X .

From the general population that volunteered for the investigation, thirty-two subjects, R_1 and R_2 , were simply random subsets with approximately the same number of S s per subset.

TESTING INSTRUMENTS

Each of the S s were individually interviewed according to the experimental design during which they were given the abstract preference survey and three Piagetian-type tasks.

The three tasks chosen for this investigation were the equilibrium in the balance, conservation of volume using metal cylinders in water, and the bending rods: separation of variables. Of the total possible tasks developed by Jean Piaget these three were selected for two reasons. First, these three tasks are commonly used in similar studies, and, therefore, results from this, and other, studies can be compared. Second, these three tasks have some overlap in their possible scores to provide a kind of concurrent reliability.

Also during the interview each S was given the abstract preference survey. This survey was developed by the author based on a similar survey developed by Fazio and Dunlop (1976). A discussion of this survey can be found in the Instrument Validation section, Appendix F.

INDEPENDENT VARIABLE

General Physics I. This course is one of several physics courses offered at Kansas State University and introduces the student to a comprehensive study of traditional physics. The majority of the students who enroll in this course are in their sophomore or junior year while a few may be in their freshman or senior year. The student is required to attend lectures, recitations, and a weekly laboratory where they are introduced to math-oriented concepts, hands-on laboratory experiences, and demonstrations. General Physics I is required course for those who are majoring in pre-medical, pre-veterinarian, pre-dental, construction science, and geology. Because acceptance into pre-medical, pre-veterinarian, and pre-dental depends on a good undergraduate record, there is keen competition for the higher grades, and the grades in General Physics I and II are no exception.

DEPENDENT VARIABLES

1. Cognitive development. The organization process of intellectual operations, structures, schema, and processes toward greater cognition. According to Piaget, there are three basic factors which affect one's cognitive development: experience acquired from the environment, the social milieu, and maturation of the nervous system.

2. Abstract preferences. When faced with a problem situation, the individual will initiate some action toward solving the problem. Since the solution may exist in several different approaches of varying degrees of abstractness, that action the individual initiates toward the problem situation indicates his abstract preference. Any actions are grouped as being either concrete or abstract.

DATA COLLECTION METHODS

From the set of Ss who volunteered for the investigation two subsets were formed, at random, of approximately equal numbers. One subset, R_1 , was scheduled to meet for individual interviews during the first two or three weeks of the semester and the last two or three weeks of the same semester. The other subset, R_2 , was scheduled to meet for individual interviews only during the last two or three weeks of the same semester. Each interview lasted approximately thirty minutes.

During the interview, the individual was asked to complete the abstract preference survey. Once that was completed the individual was presented the three Piagetian-type tasks. The first task was the Conservation of Volume using metal cylinder in water. The next task was the Separation of Variables: Bending Rods followed by the Equilibrium in the Balance. The presentation of these tasks was in accordance with the standard protocol established by Jean Piaget including appropriate questions, and statements. All conversations during the tasks were tape recorded for later examination and scoring. The protocol and scoring for these three tasks has been appended.

DATA ANALYSIS

Because of the experimental design used in this investigation it is necessary to show the equivalence of the groups R_1 and R_2 . To do so O_2 and O_3 for the preference survey, and for the tasks (II and III) were analysed using the t-test.

The t-test was also used in analysing any changes in the pre-test to post-test average scores for the preference survey and for the tasks.

To check the effects of testing for the tasks and t-test was used to analyse any difference between the O_1 and O_2 average scores for Task I (Conservation of Volume).

To see if there is any correlation between the preference survey and the Piagetian tasks the Pearson Product-Moment Correlation was carried out for both the pre-test and the post-test scores.

An ad hoc analysis was carried out to show the degree to which change their preferences after actually being given the chance to solve the real problem. The chi-square test with one degree of freedom was used to the number of concrete and abstract written preferences to the number of concrete and abstract actual selections for Task I and the related question #2 on the preference survey. This test was carried out for both the pre-test averages and the post-test averages.

The scores reported in Appendix E are based on the following criteria: Abstract Preference Survey scores reflect the number of formal responses; the Piagetian tasks were scored giving a IIA level = 1, IIB = 2, IIIA = 3, and IIIB = 4.

Chapter 4

RESULTS

The data from Table 1 is used for the following evaluations. To establish the equivalence between groups, R_1 and R_2 , the t-test was run on both the Abstract Preference and the Piagetian tasks II and III post-test scores (Table II).

Table 2

Equivalence of groups, R_1 and R_2 , using post-test scores				
Group	N	\bar{X}	s^2	t
Tasks II and III				
R_1	18	6.50	.971	.214
R_2	14	6.57	.725	
Abstract Preferences				
R_1	18	7.61	2.487	.059
R_2	14	7.64	2.093	

A comparison between groups with respect to their abstract preference scores and their scores on the selected Piagetian tasks indicated that there was no significant difference in either case. It is, therefore, concluded that the two groups tested were equivalent in the beginning.

To test the hypotheses H_1 and H_2 the t-test was performed on the

group R_1 's mean pre-test and post-test scores for the selected Piagetian tasks, and the Abstract Preference Survey (Table III).

Table 3

Pre-test-Post-test Differences for the Survey and Tasks				
Group	N	\bar{X}	s^2	t
Tasks II and III				
R_1 pre-test	18	6.11	.928	.053
R_1 post-test	18	6.50	.971	
Abstract Preferences				
R_1 pre-test	18	6.78	3.124	1.492 ^a
R_1 post-test	18	7.61	2.487	

^a $p < .20$

The results indicate that H_1 must be accepted, i.e. the null hypothesis that there is no significant difference between the mean pre-test and post-test scores for the selected Piagetian tasks. H_2 , however, must be rejected in that there was a significant difference, though mildly, between the mean pre-test and post-test scores on the Abstract Preference survey.

Though the experimental design takes into account the effects of testing, it was further checked by comparing with the t-test the mean scores of R_1 on the pre-test Conservation of Volume task with R_2 on the post-test Conservation of Volume task (Table IV).

Table 4

Differences Between O_1 and O_3 for Task I				
Group	N	\bar{X}	s^2	t
Task I				
R_1 pre-test	18	2.67	.235	.782
R_2 post-test	14	2.79	.181	

The lack of significant difference indicates that the effects of testing may not be a contributor to the investigation's hypothesis concerning cognitive development and helps to support the results found in Table III.

To test H_3 , that there is no significant difference between a subject's abstract preference score and his abstract ability, the product-moment correlation coefficients were determined for both R_1 's pre-test scores and R_2 's post-test scores. In both cases the preference scores were matched with the sum of the scores for tasks I, II, and III (Table V).

Table 5

Differences Between Abstract Preferences and Ability			
Group	N	r	level of significance
R_1 pre-test	18	.22	NS
R_2 post-test	14	.04	NS

The results in Table V indicate that the null hypothesis, H_3 , must be accepted for both the pre-test and post-test scores. From the r-values it can be noted that the correlation deviates greater for the post-test scores than it does for the pre-test.

A posthypothesis, H_4 , was developed after the initial study which relates how a subject responded to question 2 on the preference survey and their score on the Equilibrium in the Balance task. It is assumed that both situations are related with the obvious difference that one is a hypothetical problem while the other presents to the subject the actual problem. The posthypothesis is written in null form:

H_4 : There is no significant difference in how a subject responds to question 2 on the preference survey and his score on the Equilibrium in the Balance for both pre-test and post-test situations.

To test this hypothesis the scores were designated as being either concrete or formal. For the task both IIA and IIB scores were grouped as concrete while IIIA and IIIB were grouped as formal. From the survey, the more abstract response was given the formal designation. The chi-square test was run for both pre-test and post-test scores as shown in Table VI.

Table 6

Differences Between Actual Selection and Written Preference for Task I

PRE-TEST

		Actual Selection	
		concrete	formal
Written Preference	formal	0	7
	concrete	4	7

$$\chi^2 = 5.7^a$$

^aFor 1 d.f. chi-square (.02) = 5.41, (.01) 6.64

POST-TEST

		Actual Selection	
		concrete	formal
Written Preference	formal	1	11
	concrete	1	5

$$\chi^2 = 1.76^b$$

^bFor 1 d.f. chi-square (.20) = 1.64

Based on these results, the null hypothesis must be accepted for the pre-test situation but is mildly significant for the post-test. Whereas, in the pre-test situation the subjects were more likely to change their preferences, in the post-test situation they were less likely to make any shift.

Chapter 5

DISCUSSION

Within the limitations of this study it is generally felt that the questions raised at the beginning were answered. To review, the questions were:

- (1) Can instructional procedures and active participation in an introductory college physics course successfully affect the transition from concrete to formal cognitive functioning as described by Jean Piaget?
- (2) Can instructional procedures and active participation in an introductory college physics course successfully affect the transition of a student's abstract preferences toward problem solving from concrete to formal approaches as indicated by the abstract preference survey?
- (3) Could abstract preference be another factor that might influence one's choice of approach when faced with a problem situation other than cognitive ability?

In the case of question one, there appeared to be no promotion of cognitive ability as was measured using the Equilibrium in the Balance and the Bending Rods Piagetian tasks. It was not expected to find any changes based on similar studies cited in the Review of the Literature, and when taken in light of Piaget's theory of cognitive development. Based on the findings, the null hypothesis, H_1 , had to be accepted.

Question two was raised because the author noted from the studies by Fazio and Dunlop that science majors were more likely to prefer a more abstract approach on the preference survey than did non-science majors on the same survey. The results from the author's study seem to indicate that General Physics I had some positive effect in modifying one's abstract preferences. The subjects at the end of the study had a greater tendency to choose the more formal approach to problem situations. In answering question two, the null hypothesis, H_2 , had to be rejected.

The question of correlating preferences to ability was a result of the first two questions. The results of the study showed that there was no correlation in either the pre-test or post-test situation, thus, leading to the acceptance of the null hypothesis, H_3 . The similar study by Fazio and Dunlop had shown no correlation, also.

The third question raised by the author has strong implications on the usage of pencil-and-paper type tests being developed to measure cognitive ability. Whereas, it is indicated from this, and Fazio and Dunlop's, study the lack of correlating the preference survey with cognitive ability raises some doubt on the validity of the usage of present pencil-and-paper tests. The change found in this study with a student's abstract preferences, as opposed to no change in cognitive ability as measured with the selected tasks, might shed some light on those studies claiming positive changes in cognitive ability when the students were given the pencil-and-paper test as opposed to the classical method developed by Jean Piaget. This study indicates that problem solving is not merely a matter of cognitive ability; other factors seem to be involved.

The ad hoc analysis which compared a subject's abstract preference,

on question two of the survey, with the task Equilibrium in the Balance revealed that at the beginning of the treatment there was no correlation between one's preference and actual method in solving the balance problem. However, at the end of the treatment there was a significant shift to such a correlation. It is implied from the study that the treatment might have had a positive effect on matching one's preference to one's actual method when faced with the balance problem regardless of ability. The study by Fazio and Dunlop had shown the degree of abstractness present in an individual's preference for a particular method to solve a problem does not appear to be directly related to that individual's abstract ability. Their study went on to show, using three similar situation questions, that, for many students, actual preferences are task dependent. This study seems to support that contention with its findings.

One should note from the results in Table 5 that in both the pre-test and the post-test situation, there were those students who demonstrated formal operational thinking with Task I but stated a less abstract preference on the hypothetical situation presented in question #2. What may be the reason for this mismatch might be illustrated in the following example. The two electronic diagrams were provided in Elementary Electronics/Science & Electronics magazine, Volume 20, No. 6, pages 34 and 35, shown in part. As illustrated in Table VII they both represent the same project. In the first case the illustration uses formal symbols common to electronics. The other diagram uses familiar drawings of the actual parts along with their respective positions and wirings as would be on the actual board. Which diagram would you

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prefer to use in assembling the project?

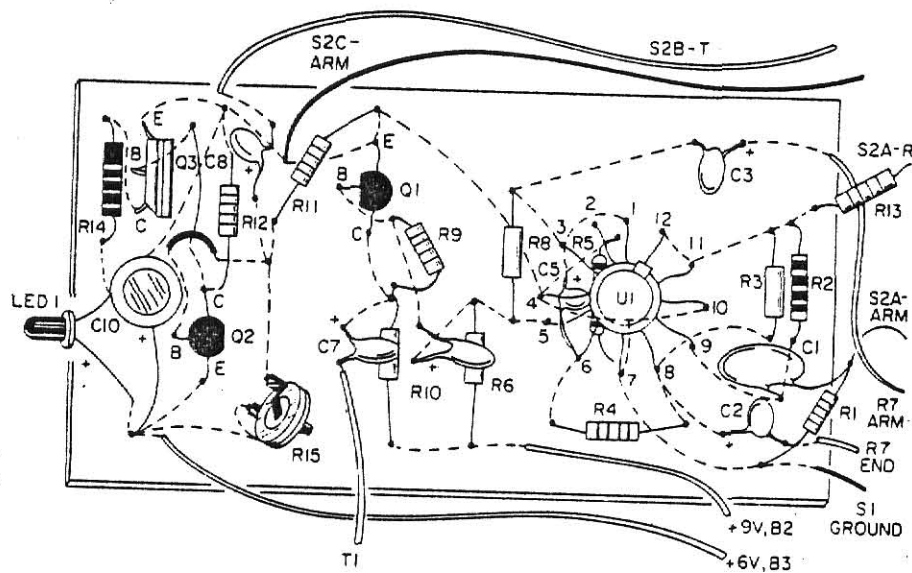
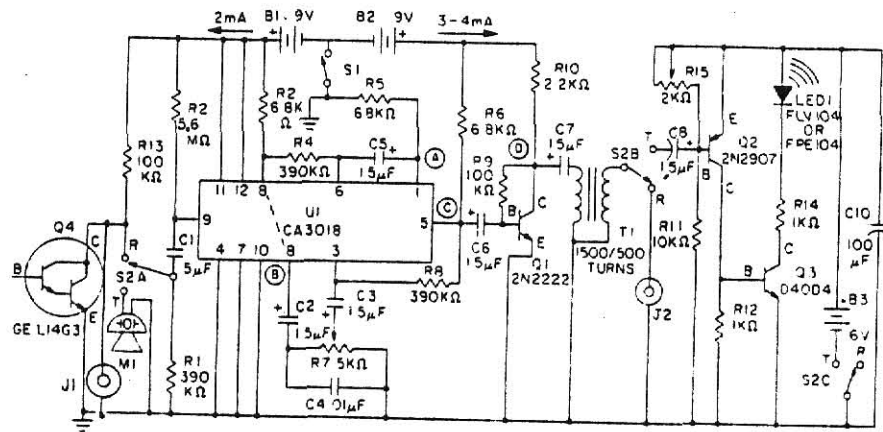


Figure 1.

Students in lab-science courses are often faced with both hypothetical and real problem situations. In some cases, what is shown in lecture might have to be demonstrated in the lab. If the lab and lecture combination are to have optimum effects for the student, then it is important to understand what affect the student's preference might have on problem solving.

Jean Piaget has stated that formal operational is not so much a specific behavior as it is an "orientation" to problem solving. If this is the case, it can be implied from this study that abstract preference should be considered when evaluating the effects science may have on mental development.

CONCLUSIONS

Conclusions based on this investigation are as follows:

- (1) Active participation in an introductory college physics course does not appear to raise the cognitive levels of the student.
- (2) A student's abstract preference toward a problem situation may not be correlated to his cognitive ability.
- (3) This study indicates that a student's abstract preferences can be modified by participating in General Physics I.
- (4) Other factors possibly exist that might affect how a student may perceive a problem situation other than cognitive ability such as abstract preference.

RECOMMENDATIONS

Further studies need to be carried out with students in such intro-

ductory physics courses which emphasize concrete experiences in contrast to the General Physics I setting.

The development of pencil and paper type tests for evaluating cognitive development need to consider student preferences when constructing test items.

The investigation of other factors which might affect the problem solving process needs to be carried out at all levels of grade and stages of mental development.

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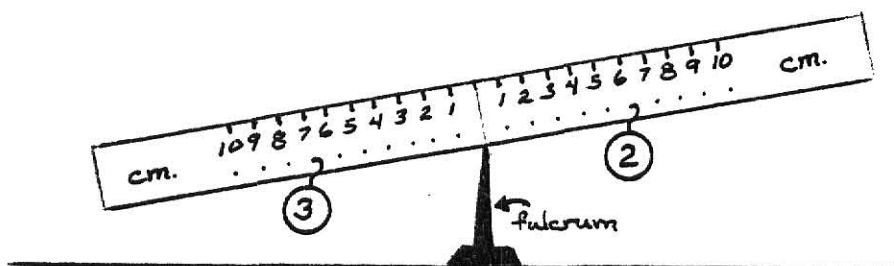
APPENDIX A

ABSTRACT PREFERENCE SURVEY

This survey is part of a study used in developing curriculum materials for college students. We are interested in how college students react to some problem situations. Do not worry about your answer being right or wrong; this is not a test. There are no right or wrong answers--only preferences. (Assume all methods could, if properly used, result in a correct solution.) As you read each item, select the method which YOU would prefer to use in arriving at the solution. You need not actually solve the problem at this time--just indicated which method you would prefer to use if someone asked you to solve the problem. Some of the problems may be harder for you than others, but there are no "trick" questions or solutions.

1. You have found an interesting "rock" while vacationing in the mountains and wish to know what it is, thinking it might be valuable. Which would you prefer to do to identify it?
 - A. List some of the rock's characteristic properties and then consult a book listing rocks and minerals and their properties. You select one from the book that has properties matching those of your rock.
 - B. Compare your sample to those in a collection of labeled rocks and minerals for one that "looks" like yours.

2. A 2 gram weight is placed exactly 6 cm to the right of a fulcrum. Another weight, 3 grams, is placed 7 cm to the left of the fulcrum:

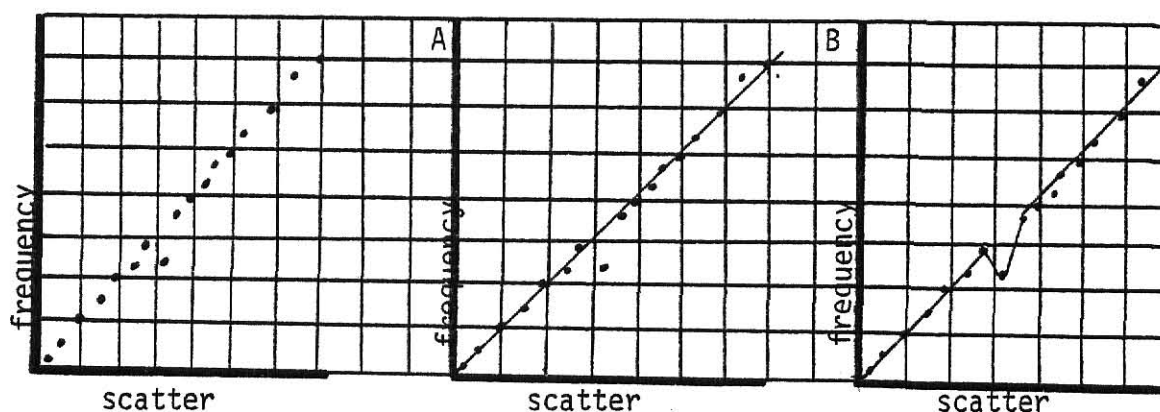


- Where would the 3 gram weight need to be placed to have the system balanced? To answer the question, which of the following methods would you use?
- Use the mathematical relationships you are given and calculate the exact position.
 - Actually manipulate the weights until the position is found for the system to be balanced.
3. You are given a block of unknown composition, and you are given its weight and size. You wonder if it will float if placed in various liquids such as alcohol, machine oil, gasoline, and bleach. How would you prefer to determine if this object would float in each liquid?
- Place the block, under controlled conditions, in each of the liquids and observe the results.
 - Calculate the object's density from a formula you are given and compare it to the densities of the various liquids (also given) to see if the block's density is less (and therefore will float).
4. You are given a collection of minerals and are asked to group them accurately according to some property(s) each group you make will have in common. You are also given several properties for each mineral. Which property(s) would you prefer to use to separate the minerals into respective groups?
- HARDNESS and SPECIFIC GRAVITY based on standardized scales.
 - COLOR based on a standardized scale of color

5. In an experiment you made a blue powder that is to be placed in a bottle and stored until next week where it will be used in another experiment. You are asked to label the bottle as to its contents. The instructor identifies the chemical in two ways. Which would you prefer to use in identifying the bottle of chemical?
- A. CuSO_4 (its chemical formula)
 - B. Copper Sulfate (its name)
6. You are given some pieces of wire, a battery, two light bulbs, and some switches for an experiment. The object of the experiment is to develop an understanding about simple electrical circuits and the flow of electricity in those circuits. This can be done, as explained in the lab introduction, by hooking-up the pieces in such a way that both lights glow at the same time. To accomplish the objectives of this experiment, which would you prefer to do?
- A. Devise YOUR OWN procedure for the experiment that you will follow that will result in the completion of the objectives.
 - B. Follow a detailed set of instructions you are provided giving step-by-step procedure for successfully getting the expected results.
7. You want to learn how the parts of an electrical motor fit together. In addition, you want to learn this as quickly as possible. Which of the following would you choose?
- A. Take an actual electric motor apart and see how the parts fit together.
 - B. Look at the diagram and read how the parts go together for that motor.

8. You are given the task of determining a person's blood type. Which of the following best describes the method you would prefer to use in this determination?
- A. Using a sample of blood provided, you would test it in a laboratory to determine its type.
 - B. Using an accurate family tree showing blood types of many blood relatives, (but not the one in question) you would determine the blood type of the individual by applying various principles of heredity and genetics which would be provided for you.
9. You are ordering several types of cut flowers. You want to make as many combinations, using eight flowers at a time, for display without duplicating any combination. You will be paid \$3.00 for each different combination. You know you will use equal numbers of each type, overall, but you do not know how many combinations you will make. How would you prefer to find out how many combinations you would make?
- A. Using an equation you are given for calculating the number of combinations any number of things will make taken any number at a time, calculate the number of calculations.
 - B. On a sheet of paper, using symbols to represent the types of flowers, make as many different combinations of those symbols as you can.
10. You are to make a bunch of cookies for a group picnic. Your recipe is for making four dozen but you are asked to bring nine dozen. Which would you prefer to do?
- A. Make two batches (8 dozen) and then, using another recipe for making one dozen cookies, add another batch of one dozen to give a total of nine dozen.
 - B. Using proportions, calculate the amount of ingredients needed for making nine dozen in one batch.

11. You wish to investigate the effects of the weather on plastic. Which would you prefer to do to best understand the effects of weather on plastic?
- A. Place several pieces of plastic outside where it will be exposed to the weather and carefully record observations to formulate results at the end of the study.
 - B. Expose pieces of the plastic in the laboratory to simulated weather conditions (dry, wet, cold and wet, etc.) and carefully record observations to formulate results at the end of the study.
12. You have just completed an experiment where measurements were made using a variety of instruments including a stopwatch, a collection of samples to be tested and some calculations. The plotted points from the experiment are shown at the left. You are asked to draw a "curve" based on the data that shown the relationship between the two variables that were tested. Which curve would you prefer to use?



APPENDIX B

CONSERVATION OF VOLUME

The materials are placed in front of the student. The interviewer then begins the following dialog:

"I have a couple test-tubes here I would like you to look at. They are both as identical as possible. And, they are filled as closely as possible with equal amounts of water. I would like you to take a look at them and see if you are satisfied that they are, indeed, both equal. If not, I have a medicine dropper with which you can make them equal on your judgment."

When the subject is satisfied that both water levels are equal he is next shown the two metal cylinders.

"I have a couple of metal cylinders here. I would like to show you that both cylinders have the same length and are just as round and therefore have the same dimensions. I would like for you to hold them each in your hands, and tell me how they are obviously different."

The subject should note the distinct difference in weight, state so, and estimate how much heavier or lighter one cylinder is to the other. The subject is asked to hold the heavier cylinder while the interviewer takes the lighter one for the next part of the interview.

"I am going to take the lighter one and lower it into this test-tube, and I would like you to tell me what is going to happen to the water level."

The subject should note that the water level shall rise. The cylinder is then lowered into the tube to show that the observation is correct.

"Before you lower your cylinder into the other tube, I would like for you to place this rubber band at the level where the water will be after you lower it."

After the subject positions the rubber band he is asked, "Why did you place the marker there?" After the subject has provided his reasoning he then lowers the cylinder into the tube to observe the results. If the subject predicts incorrectly (or correctly giving the wrong reason) the interviewer asks what the subject thinks caused the levels to come out the same.

SCORING

- IIA - the subject makes an incorrect prediction or predicts correctly using an incorrect reason; can't explain the results after the subject sees the experiment performed.
- IIB - the subject makes an incorrect prediction or predicts correctly and gives an incorrect reason; however, when the subject sees the experiment performed he realizes the correct explanation.
- IIIA - the subject predicts correctly and gives a correct reason.
- IIIB - this task does not require IIIB level of thought.

SEPARATION OF VARIABLES: BENDING RODS

The apparatus is placed in front of the subject and the interviewer begins the following dialog:

"I have an apparatus here which has a variety of rods attached to a support and these rods' length can be changed as I show you here, if you wish, and at the end of each rod is a hook from which you can hang some weights."

The interviewer then allows the subject to examine the apparatus touching the rods and changing their lengths.

The interviewer says: "Look at the rods and tell me as many ways as you can how the rods are different." The interviewer asks leading questions until the subject recognizes the four ways in which the rods are different (length, size, shape, and materials) and is told that these differences are called variables. The interviewer now re-states the four variables.

The interviewer next says: "I would like you, now, to do some experiments with these rods to show me the effect each of these four variables has on how much the rods bend when a weight is placed on the end." The subject is being invited to show at least one experiment to show the effect of one of the variables on the bending of the rods.

If the subject is unclear as to what is expected the instructions are given again.

If the subject does not provide at least one experiment (III A level) the interviewer provides the opportunity to reach at least the II B level by providing the following leading question: "Take one thick rod and one thin rod and make them bend the same amount using identical weights." The

II A student does not demonstrate any logical manipulation.

If the subject succeeds with one experiment the interviewer then asks: "What else can you do to test the other three variables?"

Some leading questions used during the task, but not before an opportunity to set up at least one experiment has been provided is: "What can you do to prove that the length (shape, diameter, or material) of the rod is important in determining how much it will bend?"

At the end of the interview the subject is asked: "Is there anything else you want to do with this apparatus?"

Other questions asked during the interview are:

"What are you showing with that experiment?"

"What variable is your experiment dealing with?"

"How does your experiment show what variable you are testing?"

SCORING

IIA - the subject cannot explain logical manipulation.

IIB - the subject can explain logical manipulation (intuitive feeling that long and thin balances short and heavy).

IIIA - the subject successfully shows at least one experiment that proves the effect of at least one variable.

IIIB - the subject solves the entire problem.

EQUILIBRIUM IN THE BALANCE

The apparatus is placed in front of the student. The following dialog is begun:

"I am going to place this bar on this apparatus so that it can pivot at the center. You will notice that it is worked off in fifteen equal units to the left and fifteen equal units to the right and is essentially balanced on the pivot. I also have a couple hooks that can be placed on the bar from which we can hang weights. We are going to do some balance tasks."

The interviewer proceeds with the following steps:

1. "I'm going to take 100 grams and place it at the sixth position and I would like for you to take this 100 grams and place it on the balance in such a way that the bar is again balanced." The interviewer holds the bar level while the subject is handing the weight, and before releasing it asks this question: "Why did you hang the weight at the _____ position?"
2. "I'm going to leave my 100 grams at the sixth position, remove your 100 gram weight, and give you two 50 gram weights. Where will you hang your 50 gram weights to balance my 100 gram weight?" The interviewer holds the bar level while the subject decides where to place the two 50 gram weights. Before releasing the bar, the interviewer asks: "Why did you hang the 50 gram weights at the _____ position(s)?"
3. "I will now remove the weights and place 120 grams at the third position from the center. I would like for you to balance the bar using this 40 gram weight." While holding the bar level as before,

the interviewer asks: "Why did you place the 40 grams at the _____ position?"

4. "I will now remove the weights and place 120 grams at the fluid position from the center. I would like for you to balance the bar using this 40 gram weight." While holding the bar level as before, the interviewer asks: "Why did you place the 40 grams at the _____ position?"
5. "Next, I'm going to hand a 70 gram weight at the tenth position. Hang a 100 gram weight on the other side to balance the bar." The interviewer holds the bar level while the subject places the 100 gram weight after which the interviewer asks: "Why did you hang your 100 grams at the _____ position?"

If the interviewer is unsure of the subject's judgment after using the 70/100 weight combination, a 60 gram weight at the sixth position and the subject is given a 40 gram weight. The same dialog as above is used.

SCORING

- IIA - the subject is unsuccessful with anything beyond step two.
 - IIB - the subject is successful with step three. The explanation must include the use of the proportional concept.
 - IIIA - the subject is successful in balancing the bar in step four and includes the explanation of the proportion concept.
 - IIIB - the subject is successful in balancing the bar in step five. The explanation must include the proportion concept.
- Note: A student who solves a problem using a rule such as weight times distance on one side is equal to the weight times distance on the other is using an algorithm, without necessarily using proportional reasoning. If this is so, the interviewer asks, "Can you give me

another solution using weight and distance in some other way?" If the student cannot satisfactorily do so using proportions, a lower score is given, depending on the last level for which a satisfactory explanation was given.

APPENDIX C

Kansas State University
College of Education, and
Department of Physics

Re: Student survey request

Name: _____
Year: Fr So Ju Sr Other
Major: _____
Have you had any previous
experience in physics? _____

In a continuing effort to provide the student with meaningful experiences in their education, students are asked from time to time to provide voluntarily information to be used in the development of the curriculum. A survey is being conducted this semester, with students enrolled in General Physics, and we are asking the students to participate voluntarily. Your cooperation will help the survey administrators find answers to questions and ultimately lead to the design of physics laboratory and classroom experiences meeting the student's needs. The survey is being conducted under the guidelines established by the University and with the cooperation of the Physics Department.

Two surveys, given on different dates, will be conducted. The time required to complete each survey will be approximately thirty (30) minutes. Your participation in both surveys will be needed and will be scheduled at your convenience. The survey is NOT a required part of the course and your grade in the course will not be affected in any way whether you participate or not. In addition, your responses will be anonymous and will be examined only the administrators of the survey.

If you wish to help us in our efforts and/or wish to receive further information about the survey, please so indicate in the appropriate box below. If you check YES you will be contacted within two class days. It is through your cooperation that the development of classroom materials for students enrolled in physics may continue.

- ☐ YES, I would like to participate.
- ☐ YES, I wish to receive further information.
- ☐ NO, I cannot be available to participate.

Informed Consent

After reading this document, please indicate, by your signature in the space provided below, your willingness to participate as a subject in the research as described. This survey is to be conducted under the direction of the College of Education and the Department of Physics. Dr. Robert K. James is the major advisor. Ted W. Geisert is the principal investigator.

The surveys pertain to how college students react to some tasks and problem situations. The method of accomplishing these tasks is clinical, however. You will be questioned orally during the performance of the task according to well established protocol. Questions and responses will be recorded on audio tape and your actions observed and recorded by the interviewer.

It is hoped that the analysis of the nature of the responses in given situations will enable the identification and of thought processes of college students taking college physics. Such information will lead ultimately to the design of laboratory and classroom experiences commensurate with said thought processes.

Any inquiries which you may have concerning procedures will be answered at any time.

You are free to withdraw your consent and to discontinue participation at any time.

Your responses will not be identified with you in any way as all names and references to names will be encoded. All data will be destroyed after completion of the project which, after giving reasonable time for response to criticism of the research, will be no later than July, 1978, or approximately six months.

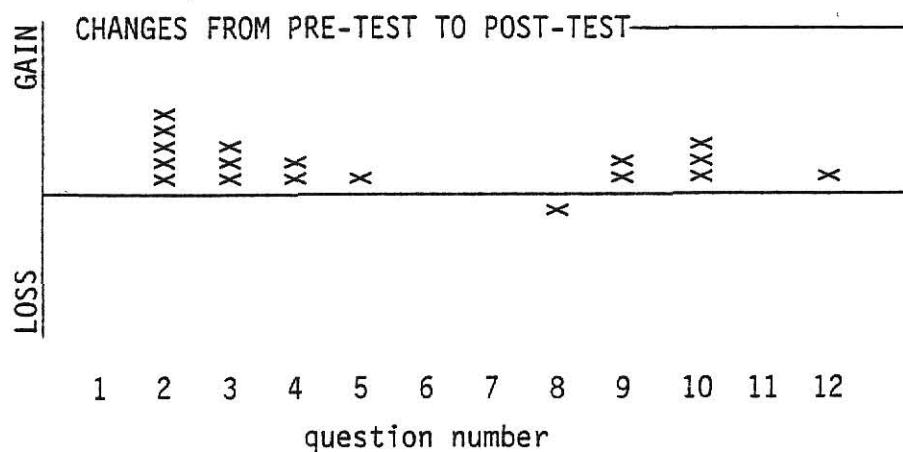
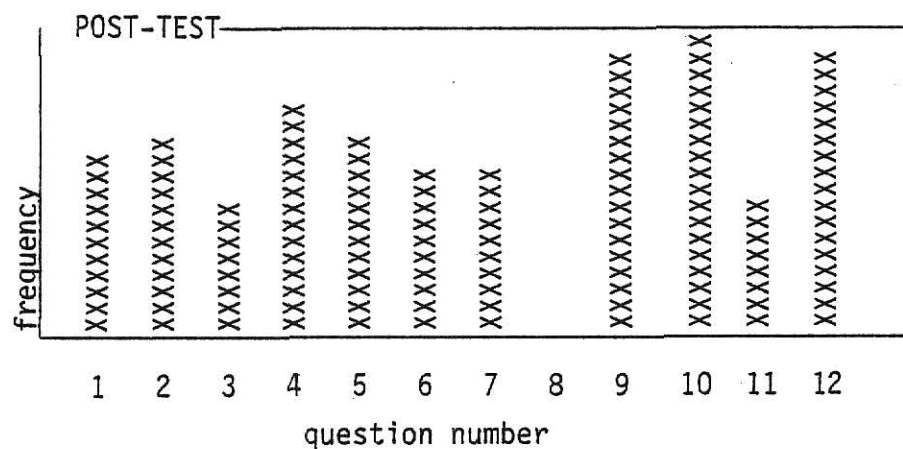
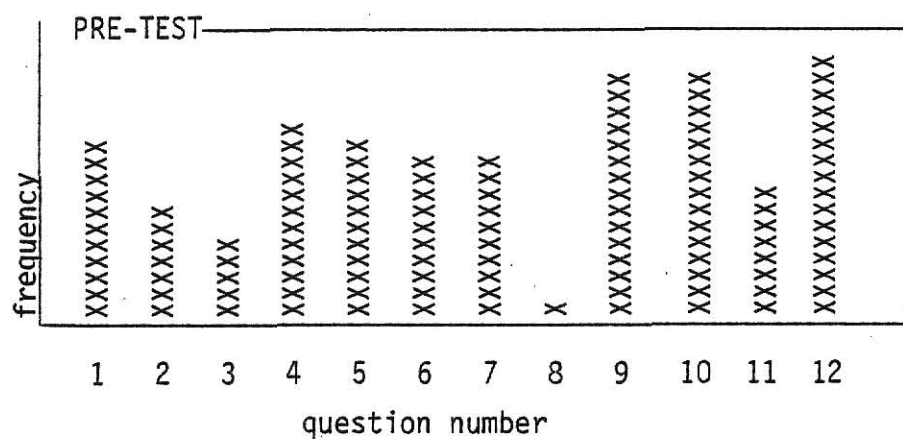
Personal information will be limited to name, birth date, classification, major, and previous experiences in science.

Signature

Date of Birth

APPENDIX D

The number of formal responses on the Abstract Preference survey by question for both pre-test and post-test scores for the group R_1 .



APPENDIX E

TABULATED RAW DATA FROM INVESTIGATION

SUBJECT #	PRETEST					POSTTEST				
	PREFERENCE	TASK I	TASK II	TASK III	SUM I+II+III	PREFERENCE	TASK I	TASK II	TASK III	SUM I+II+III
10	7	3	2	2	7	8	-	2	2	4*
11	8	3	3	4	10	9	-	4	4	8*
12	8	2	3	3	8	7	-	4	3	7*
13	4	2	3	3	8	7	-	3	3	6*
14	6	2	3	2	7	6	-	3	2	5*
15	7	3	3	3	9	9	-	3	3	6*
16	6	3	3	3	9	5	-	3	3	6*
17	5	3	3	2	7	6	-	3	4	7*
18	8	3	4	3	10	8	-	4	4	8*
19	5	2	4	3	9	5	-	4	3	7*
20	8	3	4	4	11	9	-	4	3	7*
21	6	3	3	3	9	6	-	3	3	6*
22	9	3	3	3	9	9	-	3	4	7*
23	10	3	4	3	10	10	-	4	3	7*
25	3	3	4	3	10	8	-	4	3	7*
26	8	2	3	2	7	10	-	4	3	7*
28	7	3	3	3	9	7	-	3	3	6*
29	7	3	3	3	9	8	-	3	3	6*
31						8	3	4	3	10
32						7	3	4	3	10
33						6	3	3	3	9
34						10	3	4	4	11
35						5	3	4	3	10
36						8	3	3	4	10
37						7	3	3	3	9
38						9	2	2	3	7
41						7	3	4	3	10
42						6	2	3	4	9
44						8	2	3	2	7
45						8	3	3	3	9
46						8	3	4	3	10
47						10	3	4	3	10

* these scores reflect Tasks II & III only; task I was not measured

Preference scores reflect the number of formal preferences of the twelve-item survey

The tasks are scored accordingly: IIA = 1, IIB = 2, IIIA = 3, IIIB = 4.

APPENDIX F

20

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INSTRUMENT VALIDATION: ABSTRACT PREFERENCE SURVEY

The concept of an abstract preference survey was initiated by David Dunlop and Frank Fazio, where a total eighteen question items were developed each followed by two approaches that might be considered to solve the problem. The methods of solution were ranked by a panel according to the degree of abstraction for each problem. They claimed a test-retest reliability of 0.84.

The author received a copy of this survey from which some items were taken and others were self-developed to meet the needs of the investigation. The validity of the preference survey was based on the theoretical construct for concrete and formal as described by Piaget's theory of mental development. A concrete preference can be characterized as real object orientation while an abstract preference demonstrates mental manipulation, deductive reasoning, and the lack of need for real objects. The development of each survey item was based on any of the characteristic properties that were listed in the review of the literature.

The solutions for each item was considered to be a working method which could lead the resolution of the problem. Also, each solution was not necessarily "concrete" or "formal" but one solution was to demonstrate more abstraction than the other. For scoring purposes one was designated as concrete and the other solution as being formal. It was NOT the author's intent to develop a substitute for evaluating mental development. The survey was developed to test the contention

that other factors might be instrumental in the way a student might respond on the pencil and paper tests that have become popular in evaluating cognitive development.

PIAGETIAN THEORY AND ABSTRACT PREFERENCES OF COLLEGE STUDENTS
TAKING GENERAL PHYSICS I

by

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ABSTRACT

This investigation addresses itself to the following questions:

- (1) Can instructional procedures and active participation in an introductory college physics course successfully affect the transition from concrete to formal cognitive functioning as described by Jean Piaget.
- (2) Can instructional procedures and active participation in an introductory college physics course successfully affect the transition of a student's abstract preferences in problem solving from concrete to formal approaches as shown by an abstract preference survey?
- (3) Could abstract preference be a factor which might influence one's choice of approach when faced with a problem situation other than cognitive ability?

The hypotheses written in null form are as follows:

- H_1 : There is no significant difference between the subjects' pre-test and post-test performance on selected Piagetian-type tasks as indicated by their mean differences.
- H_2 : There is no significant difference between the subjects' pre-test and post-test performance on the abstract preference survey as indicated by their mean differences.
- H_3 : There is no significant difference between a subjects' abstract preferences and his level of cognitive development.

The separate-sample pre-test-post-test experimental design as described in Experimental and Quasi-Experimental Designs for Research by Donald Campbell and Julian Stanley was used for this investigation.

The subjects were thirty-two students concurrently enrolled in General Physics I at Kansas State University. The subjects were divided into two nearly equal subgroups. One subgroup was given the abstract preference survey and three Piagetian-type tasks for the pre-test. The post-test given at the end of the treatment (the first semester of General Physics) to this subgroup was the same survey and two of the original three tasks (the Conservation of Volume task was excluded). The post-test-only subgroup was given the same survey and tasks as the other subgroup.

The gain scores between the pre-tests and post-tests for the survey and the tasks were compared. Analysis indicated that while there was no significant increase in cognitive levels there was a mildly significant positive gain in abstract preference. There was no significant correlation between the survey and the task scores either at the beginning of the treatment or at the end.

An ad hoc analysis comparing a subject's response on the equilibrium in the balance task and his written preference to a similar problem situation on the survey was carried out. At the beginning of the treatment there was a significant difference between the subject's written preference and actual selection in solving the problem. The post-test, however, indicated that there was a significantly smaller difference between the written and actual methods. It appears that as a result of the treatment one's written preferences will more closely match one's actual selection for certain problem situations regardless of ability.

From these results the null hypothesis H_1 was accepted and H_2 and H_3 were rejected.