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LARSEN, STIRLING DAVID
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ABSTRACT CONSERVATION TASKS AS A MEASUREMENT FOR COGNITIVE DEVELOPMENT IN ADULTS

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
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By

Stirling David Larsen

Dissertation Committee:

Ronald C. Johnson, Chairman
Robert E. Cole
Richard A. Dubanoski
Hazel Kraemer
Karl A. Minke
Michael J. Shapiro

ABSTRACT CONSERVATION TASKS AS A MEASUREMENT FOR COGNITIVE DEVELOPMENT IN ADULTS

Abstract

This paper identifies a cognitive skill that some adults have and others do not, viz., abstract conservation ability. The concept of abstract conservation is an extension of the familiar conservation problem paradigm for the purposes of the present research. It is suggested that this skill is experientially gained. This deemphasis of maturation is contrary to popular Piagetian beliefs. Recent work in cognitive development indicates there may be types of development beyond what Piaget calls the Formal Operations period. Piaget implies that any further development beyond or during this period is quantitative. It is possible that a few skills identified in this research, including abstract conservation, constitute qualitative differences in thinking. If this is the case, current stage theories should be extended. Subjects were 94 community college students over 18 years of age, 36 of whom had experience in college physics classes and 58 of whom did not. The independent variables were whether or not students had experience in college physics, whether or not they received a demonstration on concrete conservation problems prior to performance on abstract conservation problems and whether or not they

received additional sensory feedback during performance. The main hypothesis states that experience in college physics courses will make a difference in the abstract conservation abilities of the subjects. Two sub-hypotheses also imply that differences in abstract conservation skills will occur. One of these says that a demonstration in concrete conservation will make a difference. The other states that additional sensory feedback during the problem solving activities will also make a difference. Within the groups of physics and no-physics experience, subjects were randomly assigned to the other conditions. The dependent variable was the extent of abstract conservation demonstrated by each subject. Four abstract conservation problems were designed. These deal with physical concepts with which most adults are familiar. Presentation order of the problems was counterbalanced. All subjects were given the California Test of Mental Maturity prior to participating in the abstract conservation problems. After the problems were presented, each subject completed a questionnaire also designed to measure abstract conservation. Two judges independently scored the abstract conservation problems (r = .96). The two independent measures of abstract conservation ability, i.e. the problems and the questionnaire, were also correlated (r = .64). It was found that adults do have great differences in abstract conservation ability. These differ-

ences were also found to be largely experiential. Students with physics backgrounds showed better abstract conservation than students with no physics backgrounds ($\chi^2(1) = 35.17$, $p < .001$). Multiple regression analysis using physics experience, questionnaire score, I.Q., sex, grade point average, and age as predictors was significant ($F(1, 92) = 86.67$, $p < .001$). Analysis of covariance designs, with I.Q. and grade point average used as separate covariants, also yielded significant results ($F(1, 91) = 61.56$, $p < .001$, using I.Q. as the covariant and $F(1, 91) = 84.78$, $p < .001$, using grade point average as the covariant). On the other hand, whether or not the subjects received instruction or sensory feedback did not make a difference. Reasons for this are discussed. The abstract conservation paradigm was successful and easy to apply empirically. That the skill has obvious experiential resources is a challenge to the emphasis on heredity and maturational variables popular in stage theory approaches. It is suggested that as humans grow up the emphasis may change from maturational variables to environmental variables with respect to cognitive development. Implications of this are discussed with respect to stage theory, critical periods and sequential development in general and Piaget in particular.

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Current theories say little about adult cognitive development, with the exception of intelligence as studied and measured by I.Q. tests. This area has been researched and comprehensive reviews are available (Labouvie-Vief, 1977). However, with respect to styles of thinking, stage development in adulthood, or differing modes of thought, little is available.

This introduction will develop the rationale that predictable types of cognitive development continue throughout adulthood. It is also proposed that during this time the variables controlling cognitive development change from an emphasis of basically maturational (hereditary) variables to environmental (learning) variables. This is in conflict with popular Piagetian beliefs which emphasize maturational variables throughout development. The hypotheses developed are in line with these ideas. They represent specific examples of what is otherwise generally presented by the background given herein. This paper also suggests that one of the best ways to illustrate the developmental sequence of cognitive development past the adolescent years is to use conservation-type problems. Conservation problems have not been widely used with adults in the past. However, it is possible to show that conservation abilities extend to abstract as well as concrete thought processes. This expansion of the

conservation problem paradigm into abstract problems is new to psychological literature.

Stage theories have found application in several areas. Freud spoke of psychosexual stages of development and another psychoanalyst, Erikson, of psychosocial stages of development. Piaget has popularized his ideas on stages of cognitive development. More recently psychologists have become acquainted with stages involved in development toward death (Kübler-Ross, 1970) and with expanded adult stages in living and adjustment (Sheehy, 1975). Inherent in all stage theories are concepts of sequential development and also critical periods. Although the research herein does not investigate critical periods or sequential elements per se, it does identify different cognitive skills in adulthood. These must be interpreted in the broader perspective of how they may relate to any critical period, yet unidentified perhaps, or to some sequential pattern that current theory does not specify. Since not only children but adults go through stages of development (Erikson, 1950; Sheehy, 1975), it is appropriate to wonder where these stages end.

Few studies have been done on adult stages of cognitive development (Allman, 1972). However, recent research by Arlin (1975) has developed the idea that there may be a fifth stage of cognitive development beyond the last stage suggested by Piagetian theory. This fifth

stage is called a "problem-finding" stage and is distinguished from the "problem-solving" stage that is the central idea in Piaget's formal operations period of development. Gruber (1973) also suggests a type of creative thought that may be considered as a new plateau in refined cognitive development.

It is known that adults do not, by virtue of adulthood, automatically think logically, do not necessarily isolate variables that help them solve certain problems or manufacture correct hypotheses in dealing with simple problems (Allman, 1972; Kuhn & Brannock, 1976). Since Piaget postulates that these processes are part of the formal operations period (Baldwin, 1967) why do some adults attain these abilities and others do not?

Dennis (1953) also found that adults (college students) have diverging modes of thinking with respect to personification and animism. These are environmentally related types of thinking and suggest differences in cognitive development not dissimilar to the Allman (1972) and the Kuhn and Brannock (1976) findings cited above. These findings were a major consideration in developing the research suggested by this paper. What is being suggested is that improper or incomplete styles of thinking persist in adulthood and thus maturation does not appear to play an important role in the development of cognitive skills on higher (scientific) levels of performance.

The current paper involves research with adults, using forms of abstract conservation as a measure of cognitive level. Inasmuch as conservation problems are familiar, this new approach may provide a comparison that helps investigate types of adult thinking. It may also help in the understanding of sequences of cognitive development during adulthood that are yet unidentified.

The application of stage theory to cognitive development is useful since humans adhere to a known sequence during childhood and adolescence. Some steps in this sequence consist of a knowledge of object permanance around or before 24 months of age (Sigel, 1964); certain "cognitive achievements underlying conservation" (Wallach, 1963, p. 248-249) that develop early in the concrete operations period proposed by Piaget; six stages in space organization that occur in or before this concrete period (Piaget, Inhelder & Szeminska, 1960); conservation of "identity" precedes conservation of "equivalence" (Elkind, 1967); and discovery of "which variables are responsible for an effect and which are irrelevant" (Wallach, 1963, p. 266) which occurs during the formal operations period. This sequence, however, seems to become theoretically vague during adolescence. Piaget formulates the "groupings" that occur on increasingly abstract mathematical sets during adolescence (Baldwin, 1967) but does not extend his work into adult stages of cognitive advancement

other than to suggest no further qualitative changes. Recent research challenges this point of view. Wallach (1963) states "The extent to which thinking about . . . environment follows similar or different ontogenetic patterns must remain an open question at this point" (p. 270).

Fakouri (1976) states it is important to illustrate qualitative changes in sequential development before one can argue the existence of new and unknown stages. He is critical of work mentioned earlier by Arlin (1975) and Gruber (1973), suggesting the differences found constitute only quantitative and not qualitative factors. If, as suggested herein, some adults have abstract conservation skills, while others do not, this may be additional evidence of a possible qualitative difference. If this difference can be shown to be experiential, rather than maturational, it will have important implications for Piagetian theory.

Conservation problems have been used successfully to illustrate cognitive developmental changes that occur throughout development in infancy and childhood. According to Wallach (1963) "The term 'conservation' refers to the understanding that no change has occurred regarding one or more aspects of an object or relationship, despite change in other perceivable features" (p. 246). It is proposed that conservation-type problems can be used to

better understand adult cognitive sequences. Elkind (1967) says "The quantity of literature currently growing up around the conservation problems introduced by Piaget and his colleagues testifies to the significance which both Piaget and other investigators attach to these problems" (p. 15). One reason for this significance is that conservation problems clearly illustrate developmental cognitive changes in human thinking processes. In addition, they are easy to use in an experimental setting. Furthermore, some types of conservation begin in infancy, such as object permanence, and others do not emerge until middle or late childhood, such as conservation of volume. These are types of concrete conservational abilities, i.e., they deal with observable variables. It is entirely possible to design a conservation problem that is based on concepts that are not readily observable and illustrate that the ability to deal with this type of problem is an adult ability and does not necessarily occur at a given age span as do concrete conservation abilities. Thus conservation becomes an excellent way to illustrate human cognitive differences from infancy well into adulthood.

Some research illustrating the significance of conservation problems will follow, then a brief look at the conservation paradigm will precede the introduction of ways to design and use <u>abstract</u> as well as <u>concrete</u> conservation problems.

According to Piaget, et. al. (1960) "The study of how children come to measure is particularly interesting because the operations involved are so concrete . . . and at the same time so complex that they are not fully elaborated until some time between the ages of 8 and 11 . . . . A further point of interest is that questions of measurement are closely bound up with those of conservation" (p. vii).

Flavell (1963) supports the following ideas. Conservation experiments in the past have best been used as a measure of transition between pre-operational and operational thought. Flavell further states that Piaget thinks the evolution of conservation is an elaborate sequential process of cognitive actions that contains four steps which span development from pre-operational to operational thought. "One of the most important components of the transition from preoperational to concrete-operational thought is the acquisition of various conservations . . . " (Flavell, 1963, p. 245).

Conservation abilities are also known to develop sequentially as conservation of mass, then weight, and finally volume (Flavell, 1963; Sigel, 1964; Wallach, 1963). Sigel (1964) says "Conservation, like other intellectual operations, develops in a sequence" (p. 237).

It is possible that forms of abstract conservation

may constitute steps from operational to formal forms of thought. It is known that some conservation tasks yield to "schooling" (teaching or experience) and others do not (Allman, 1972). This would suggest that maturational variables may be responsible for some types of conservation and environmental variables responsible for other types. Concrete conservation tasks are achieved somewhat automatically via maturation even in unschooled children by about 10 years of age (Allman, 1972). Do adults automatically achieve all types of conservation via maturation of the brain or are some types mostly learned?

The basic form of a conservation problem involves showing the subject a situation or set of objects and making sure the subject understands what the situation is or the objects are. It is basically an identification of variables. Once this is accomplished a transformation is performed on one or more of the variables while the subject watches. The subject is then asked questions designed to find out what the subject thinks of the variables after the transformation(s) as compared to before (Flavell, 1963). A mathematical explanation of conservation paradigms is made clear by Elkind (1967). A simplified explanation follows: First S is shown to equal V. V is then transformed to V'. Finally, does S equal V'?

It is possible to extend these paradigms beyond concrete

variables. This would involve a situation where the first step would include identifying or recognizing what variables exist. Next some transformation would be performed on at least one of the variables while the subject observes. Finally the subject would be asked to account for the variables after the transformation. If one of the variables is no longer directly observable after the transformation, but was observable prior to same, this creates an abstraction of the variable and accounting for what happened to the variable would constitute a type of abstract conservation. Several problems have been designed for this research and are explained in the Method section.

Deutsch (1937) published a study which can serve as a good prototype for the research proposed herein. Although her work was done with children, she did attempt to classify cognitive functioning using certain problems and also using a questionnaire. It is also notable that her results were critical of stage theory in general and Piaget in particular. In the current ambiance of Piagetian popularity these criticisms have been forgotten, but surprisingly may still have some basis. As mentioned in the introduction to Deutsch's work, she found only a few of Piaget's many "types of causal thinking in large enough frequencies to warrant further analysis. She also found fewer non-naturalistic explanations than Piaget

reports, and no evidence for the validity of his analysis of the development of causal thinking into stages," (Deutsch, 1937, p. v).

Another point can also be extended from the Deutsch research. She summarizes that "There is conflicting evidence as to the relative roles of innate factors and experiential factors or direct training" (Deutsch, 1937, p. 13). This point, contrasting hereditary and environmental influences in cognitive theory has been mentioned previously. The remainder of this introduction, therefore, consists of comments contrasting environmental and maturational variables as related to conservation, critical periods and stage theory in general. The point is that stage theory does not necessarily need to emphasize maturation over experience, as do Piagetian ideas.

Several well-known researchers stress the importance of maturational or hereditary variables in cognitive development. Piagetian theory, in particular, relies somewhat heavily on maturational processes. It defines intelligence as an adaptive process which involves the maintenance of an equilibrium between mental structures (Flavell, 1963). Intelligence changes and grows when a challenge is encountered that disturbs the equilibrium and then mental structures change to restore it. Equilibration theory in Piaget's view does not suggest that teaching (an environmental variable) is necessary (Kuhn

& Angelev, 1976). Baldwin (1955) states that "maturation is stimulated when the child meets challenges which are not too severe" (p. 280). McGraw's (1935) ideas support a maturation interpretation of cognitive development. The maturation of the human brain, involving several critical periods, is now also documented (Schneour, 1974) and not unrelated to cognitive advancements. Some of Smedlund's research reviewed by Wallach (1963) shows that once conservation is reached it is difficult to extinguish. This may imply the existence of a critical period somewhat controlled by maturation rather than learning. White (1965) quotes Luria with regard to the critical period between the ages of four and five years: "Something very important happens in the human being in this period. . . . I think there must be some very intimate relation to maturation" (p. 211).

Research involving critical periods and emphasizing maturation has been discussed for some time by Hunt (1961) as well as others. One of the widest recognized critical periods of cognitive development in children is the developmental span between the ages of five and seven, as mentioned above. White (1965) reviews over a dozen studies evidencing changes that occur at that time.

That maturation is important in cognitive development is not the question this paper raises. It is, however, a point of this research to question the continued emphasis on maturational variables throughout the developmental span.

Perhaps there is a trend away from maturational variables in childhood to an emphasis in adolescence and adulthood on experiential variables, with respect to mental development. If this is the case, it may help account for the increased vagueness of Piagetian theory in attempting to account for developmental stages of adult cognitive advancement. The theory of Piaget is not antagonistic to experiential variables, but does not emphasize them.

Some researchers, on the other hand, emphasize environmental influences on learning that even include childhood. Over the last few decades many studies that show experience to be a major variable in cognitive development have been reviewed (Hunt, 1961; Sigel, 1964). A recent study (Kuhn & Angelev, 1976) clearly shows that experience helps cognitive development in Piagetian tasks. Wallach (1963) mentions several authors who have shown the role of experience in conservation tasks, per se. Many of the studies in recent years, such as early education experiments like Headstart, have a heavy emphasis on the environment.

The present study emphasizes experience (teaching and/or demonstration) as an independent variable in helping clarify the role of experience in adult stages of cognitive advancement. The intent is not to ignore maturation, but to suggest that as age increases the emphasis shifts to experiential factors. Certainly we are also dealing with interaction variables.

Sigel (1964) in talking about theories of development points out that while some theories, such as that of Gesell or Piaget, are mostly maturational, others are of an interaction nature. Hunt (1961) says of sequence in cognitive development that for some theorists "The order is assumed to be a fixed feature of the organism-environment interaction to be both organismic and experiential" (p. 256).

Hunt also speaks at some length about the need to "match" a cognitive level if advancement is to occur. This point is also elaborated by Kuhn & Brannock (1976) who worked with community college students, many of whom need, but do not necessarily profit from, remedial education. This point is germane to the study proposed herein as it points out that experience or maturation or both do not insure advancement if they do not occur at the right time or in the correct sequence. Further research is needed to help clarify this interaction, particularly during adulthood.

There also may be critical periods that occur late in cognitive development of which we are still unaware. Ausubel (1963) has proposed a theory stating that it is important to provide a learner with certain principles and experiences according to the ability to organize lesser categories and information. Piagetian theory, however, fails to specify adequately this interaction and implies

that maturation continues to play the more important role. This may be erroneous.

It follows that some of the assumptions of past stage theories, such as Piagetian theory, need review. One point that could be important is that while maturation may be highly important in childhood, it is less so during adulthood. Kohlberg (1973) says "It is highly unlikely that there are maturational stages in adulthood" (p. 183). In showing how adult cognitive stages of development are closely inter-related to his stages of moral development, Kohlberg (1973) points out several assumptions and problems with stage theories starting with the distinctions made in definition of quality and quantity in measuring age-related changes. Although Kohlberg's views are not inconsistent overall with Piagetian viewpoints, he does make it clear that Piaget's views do not cover adult cognitive development and that if there are adult levels of cognitive development that they are <u>experientially</u> realized.

The current research, therefore, focuses on identifying still another type of cognitive ability that some adults have and others do not have, i.e., abstract conservation skills. It may be that this ability constitutes a qualitative change and that such is not accomplished by maturational procedures alone.

The independent variables used in the research are

whether or not students have experience in college physics, whether or not they receive instructions prior to being shown abstract conservation problems, and whether or not they receive sensory feedback by participating in the problems as opposed to just observing same. These variables are all designed to be environmental. The underlying hypotheses state that all of these variables will effect the extent of abstract conservation demonstrated by each subject, which is the dependent variable. To emphasize the environmental effects, intelligence, as measured by I.Q. or a correlate thereof, is controlled.

It is also suggested that conservation is a good conceptual problem to illustrate cognitive development at any age and that conservation problems are best used to understand adult cognitive development if extended to abstract types of problems. This type of research, depending on the outcome, may or may not support theoretical ideas on stage theory, critical periods, and sequential development in general and Piaget in particular.

Method

Subjects

Community college students from Highline College, Seattle, Washington, were used as subjects. The subjects were all adults, over eighteen years of age, and would qualify, as far as age is concerned, to be classified in Piagetian terms as in the "formal operations" period of cognitive development. See Table 1 for the age distribution of the subjects.

In planning the research, it was decided to use students in physics classes who had at least two quarters of college physics experience and compare these with students having no physics experience. The nature of the abstract conservation tasks, inasmuch as they all dealt with forms of energy, was thought to favor students with laboratory experience in physics. It was then found that only approximately 20 physics students at Highline College qualified using this criterion. Inasmuch as the research design required more subjects, it was decided to use all students enrolled in any physics class. The testing was accomplished at the end of Spring quarter so that all physics students used had at least one quarter of college physics. Because of the impracticality of setting up the equipment in more than one place and also because of the time limit (the end of the school year) it was not possible to use students from other schools. Nevertheless,

Table 1

Distribution of Subjects by Age and Sex

Group	Age				Total
	20 and under	21 thru 25	26 thru 30	over 30	
Physics					
Men	13	14	2	1	30
Women	4	0	1	1	6
No Physics					
Men	16	2	3	3	24
Women	22	4	2	6	34
Total	55	20	8	11	94

approximately 40 students were now available who had a physics background. In addition, approximately 70 students with no physics background were made available from three introductory psychology classes. This made over 100 subjects available, sufficient for the research design. It turned out that four psychology students also had taken physics and these were included with the other physics students.

Three separate banks of data had to be taken on each subject, an I.Q. test, filling out of a questionnaire, and completion of the abstract conservation tasks. Attrition resulting from inability to have complete data on each subject yielded a total of 94 subjects whose data was complete for analysis. Those with a physics background totaled 36, consisting of 30 men and 6 women. Those with no physics totaled 58, consisting of 24 men and 34 women. Therefore, 61.7 per cent of the total sample had no physics and 38.3 per cent did. Each of these groups was then randomly divided into the four groups required by the design, resulting in eight groups. The four physics background groups were approximately equal in size and the four no-physics background groups were also approximately equal in size.

The experimental conditions pertaining to each group of subjects as well as the final number of subjects for whom data was analyzed in each of the groups are explained

and clarified in Table 2.

Apparatus

Before describing the apparatus, it is helpful to mention that two types of problems were used to test for abstract conservation. These types were temperature problems and motion problems. Each of these types was represented by two separate problems, making a total of four problems, i.e., two temperature and two motion problems. The temperature problems were named the rock problem and the candle problem. The motion problems were called the bicycle problem and the ball bearing problem. Presentation of each of the problems followed the basic steps in the conservation problem paradigm; first an identification or familiarization with the variables, second a transformation was made on one or more of the variables and third the subject accounted for the variables after the transformation. The problems proved easy to use in a laboratory setting and the subjects seemed comfortable during their exposure to them.

Each of the four abstract conservation problems had its own apparatus. One temperature problem used five ordinary, somewhat smooth rocks, approximately 1½ inches in diameter. These were heated, in a small electric ceramics oven, above the boiling temperature of water. The subject was shown the heated rocks in the oven. Two or three of these rocks were then removed by forceps and placed in a pyrex dish half-filled with water. The sub-

Table 2

Experimental Conditions and the Number of Subjects for Each Group

	Demonstration on Concrete Conservation	No Demonstration on Concrete Conservation
Additional Sensory Feedback	Physics: N=9 No Physics: N=15 Total: N=24	Physics: N=10 No Physics: N=14 Total: N=24
No Additional Sensory Feedback	Physics: N=8 No Physics: N=14 Total: N=22	Physics: N=9 No Physics: N=15 Total: N=24

ject was asked to explain what happened to the heat in the rocks. The questions asked the subject are clarified in Appendix I.

The second temperature problem consisted of lighting a candle and illustrating that it was hot. The candle was then covered by a small jar until it was extinguished. The subject was asked to account for what happened to the heat generated by the candle from the time it was covered until it went out. (See Appendix I.)

One of the motion problems used a bicycle frame, mounted upside down with the pedal, chain and rear wheel intact. The purpose was to show the wheel in motion, brake the wheel to a stop and ask the subject to explain what happened to the motion. The exact questions used are given in Appendix I.

Another motion problem consisted of rolling a large (1½ inches in diameter) ball bearing up an inclined plane until it stopped and asking the student what happened to the force that kept the ball rolling upward. A pinball shooting rod mechanism was mounted at the end of a narrow inclined plane, with rails on the sides, for the purpose of propelling the ball upward. (See Appendix I.)

Photographs of the above equipment are illustrated in Appendix II.

Procedure

All subjects were told that participation in the ex-

periment was voluntary. Two people decided at that time not to participate. They were also told that the experiment concerned how adults think and that there are different styles and kinds of thinking. The subjects were informed that they could get their results upon request. A date was set with their instructors to administer the California Test of Mental Maturity (CTMM) during a class period. This is a group intelligence (I.Q.) test. Subjects were told that the test showed how they think in certain situations. The CTMM was chosen because it is a group test and because it could be administered in approximately 50 minutes (using the short form--1963 S-form Level 5) and this conformed to class time. Data from The Seventh Mental Measurements Yearbook with respect to reliability and validity sustain this as one of the best group tests available. The few subjects who were absent at the time of administration of the CTMM were eliminated from the research. The results of the CTMM were hand scored by use of a stencil, and I.Q.'s interpreted by use of the tables provided in the administration manual.

A date was then set with each individual subject for the next part of the research. Each subject was telephoned the night before the appointment and reminded of same. If they did not show up another appointment was also made by telephone. This procedure was successful and fewer than 10 subjects did not come at all. The remaining attrition,

which was also slight, occurred if they failed to hand back a questionnaire they were given at the end of their appointments for the abstract conservation problems. The appointment took between 20 to 30 minutes per subject, depending on the group to which each subject belonged. Two types of experiences were provided in line with the hypotheses to see what effects might occur. These consisted of concrete conservation instruction and a demonstration thereon and additional sensory feedback during performance on the abstract conservation problems. The subjects receiving the concrete conservation demonstration had been instructed on the basic processes of identifying variables and accounting for same across any transformations performed thereon (see Table 2). An outline of these instructions and the demonstration makes up Appendix III. Basically this instruction was designed to give an introduction to what conservation means, i.e., a definition of the concept, and then a presentation of a simple conservation of mass problem, a conservation of length problem and a conservation of volume problem, respectively. In each case, the variables were identified, a transformation made thereon, and an accounting for what happened to the variables after the transformation was made. A way to prove that entities were conserved was also included with each problem (reversability). This instruction and demonstration was given just before the subject

was shown the abstract conservation problems. Other subjects were shown the abstract conservation tasks directly, without having had the instruction or demonstration on the concrete conservation problems.

The remaining independent variable, involving direct sensory feedback for some subjects and not for others (see Table 2), was administered to the appropriate subjects by allowing them to participate in the performance of each abstract conservation problem, handling the equipment and performing the transformation themselves. Other subjects just observed the experimenter do these tasks.

The presentation order of the four problems was counterbalanced to the extent shown in Table 3. There were a total of eight presentation orders. This resulted because the two motion problems were always presented one directly after the other and likewise for the two heat problems. This seemed best inasmuch as a generalization effect was also expected.

Each problem was presented and time allowed for filling out the questions relating to that problem before the next problem was given. Upon completion of the four problems dealing with abstract conservation all subjects were asked to complete a questionnaire (see Appendix IV) designed to classify them as functioning on a concrete or formal operations level, independent of how they did on the abstract conservation problems. There were a total

Table 3

Order of Presentation

of the Abstract Conservation Problems

Order Number	Presentation Order				Number of Subjects	
	First	Second	Third	Fourth	Physics	No Physics
I	B	BB	R	C	5	9
II	BB	B	R	C	5	8
III	C	R	B	BB	5	6
IV	R	C	B	BB	5	8
V	B	BB	C	R	5	8
VI	BB	B	C	R	4	7
VII	C	R	BB	B	3	6
VIII	R	C	BB	B	4	6
					36	58

Note. Abbreviations used are Bicycle Problem (B), Ball Bearing Problem (BB), Rock Problem (R) and Candle Problem (C).

of 20 questions on the questionnaire. Nine were concrete in nature and the remainder were at the formal operations level, in Piagetian theory. These questionnaires were objectively scored, with a total of 100 points possible. Each question was worth five points. If an answer seemed correct, but was not complete, three points were given for that answer. The questions on the questionnaire were adopted from an unpublished pilot study designed to rate students cognitive styles according to Piagetian stages.

Several appropriate methods of analysis were used for processing the data when it was completed for all subjects. These consisted of chi-square and t-tests, various correlations, multiple regression analysis and analysis of variance and covariance (see Results).

The scores on the abstract conservation problems were independently judged by two judges. Both sets of scores were completely analyzed, using the above methods. The Results section reports only the analyses on the first judge's set of scores, unless otherwise noted. There were no significant differences in outcome, however, between the two sets, which were highly correlated.

Results

It was proposed that some adults would demonstrate abstract conservation and that others would not. This proved to be the case. The students with physics backgrounds were abstract conservers, while those with no physics background were not. The various types of analyses used all demonstrated this difference. It was also proposed that the variables responsible for the difference are, to a large extent, environmental. This was also confirmed. Other hypotheses stating that a concrete conservation demonstration and receipt of additional types of sensory feedback during the experiment were not confirmed. These analyses and the resultant statistics are discussed in detail below.

Before proceeding with specific analysis of the data, it will be helpful to mention that two judges independently scored the results on the abstract conservation tests. These yielded a high correlation (r = .96), which was significant (t (92) = 37.98, p .001). This resulted because an objective approach was used in scoring the abstract conservation tests (see Appendix I). Analyses were performed on both judges' sets of scores, but no differences of a significant nature in the resultant analyses were found, as would be expected with data that correlated highly. Therefore, only the first judge's scores are reported in the following analyses.

Table 4 gives the means and standard deviations of the pertinent data used in the various analyses.

The first analysis used was the non-parametric measure chi-square (see Table 5). The expected frequencies computed, comparing the students with some physics background and those with none, were significant, χ^2 (1) = 35.17, $p < .001$. Subjects who scored less than 40 as a total score on the four abstract conservation tests were classified as non-conservers in the abstract sense and subjects who scored 40 or above were classified as conservers. A score of 40 represents half of the total points possible on the combined abstract conservation problems, i.e., each problem represents a total possible of 20 points or for the four problems together a total of 80 points.

It is notable that 67.2 per cent of the students with no physics backgrounds scored less than 40. On the other hand, only 2.8 per cent of physics background students scored in this category. Evidently students who have a physics background, almost without exception, have abstract conservation abilities. As will be seen in the representation of the regression analysis, this is also the best predictor.

The next method used multiple regression analysis. A summary is shown in Table 6. The overall F is highly significant (F (1,92) = 86.67, $p < .001$). The F's in

Table 4

Descriptive Statistics of the Variables

Variable	Subjects					
	Physics N=36		No Physics N=58		Total N=94	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
I.Q.	123.64	14.26	112.12	14.12	116.53	15.17
G.P.A.	3.03	0.60	2.89	0.64	2.94	0.62
Formal Thinking	38.53	8.19	25.33	10.15	30.38	11.40
Abstract Conservation	59.17	10.34	35.93	12.56	44.83	16.30
Bicycle Problem	14.00	3.43	7.02	3.87	*	
Ball Bearing Problem	15.28	3.59	9.31	3.78	*	
Rock Problem	14.50	3.44	10.24	3.80	*	
Candle Problem	15.39	3.44	9.36	4.21	*	

*Note: Totals were not entered for the problems inasmuch as the important statistic is the difference between means.

Table 5

Chi-Square

Total Score	Department		Row Total	Row Per Cent
	Physics	No Physics		
Less Than 40	1 2.5 2.8 1.1	39 97.5 67.2 41.5	40	42.6
40 And above	35 64.8 97.2 37.2	19 35.2 32.8 20.2	54	57.4
Column Total	36	58	94	
Column Per Cent	38.3	61.7		100.00

Note: Entries in each cell of the table are

Number of Subjects
Row Per Cent
Column Per Cent
Total Per Cent

Table 6

Summary Table

Multiple Regression Analysis

Variable	F Score	Significance
Amount of Physics	86.67	$p < .001$
Questionnaire Formal Thinking Score	19.56	$p < .001$
I.Q.	3.92	$p < .05$
Sex	1.77	$p < .19$
G.P.A.	1.12	$p < .29$
Age	0.27	$p < .61$

Note: The F scores above are not independent, but take into consideration the effects of each and every variable above the one reported. For this reason even the non significant variables are included in the table.

Table 6 all take into account the variance already accounted for by each previous variable, with the exception of the F reported for physics vs. no-physics which represents that variable alone.

Using further analyses that gave F scores for each of the variables used as predictors, independent of the other predictor variables, yields $F(1,92) = 31.59$, $p < .001$ for I.Q.; $F(1,92) = 5.73$, $p < .01$ for G.P.A.; $F(1,92) = 64.85$, $p < .001$ for Formal Operational Thinking (questionnaire score); $F(1,92) = 19.09$, $p < .001$ for Sex; and a non-significant F score for age. These statistics were computed separately and are not shown in Table 6.

Another, perhaps preferable, way of looking at each variable and its significance in multiple regression is to use the correlation coefficients and test these for significance. Table 7 shows the correlations between the various predictor variables and the significance of each entry. All of these are of interest, but again age was not useful as a predictor variable. This is perhaps because all subjects were over 18 years of age, with only a few subjects over 30 years of age. With respect to sex, it appears significant, but should be disregarded. There were only six females in the physics background group of 36 students. The scores for these six women represent a small proportion when compared with the 34 female scores, of a total of 58, of the no-physics back-

Table 7

Correlation Coefficients and Significance

Variable 1	Variable 2						
	Age	Sex	G.P.A.	I.Q.	Form.	Sum 2	Sum 1
Dept.	-.062*	-.397	.111	.371	.566	.670	.697
	.553	.001	.288	.001	.001	.001	.001
Sum 1	-.087	-.414	.242	.506	.643	.947	
	.404	.001	.019	.001	.001	.001	
Sum 2	-.075	-.439	.251	.527	.634		
	.475	.001	.015	.001	.001		
Form.	-.088	-.394	.279	.593			
	.401	.001	.006	.001			
I.Q.	-.116	-.221	.385				
	.263	.032	.001				
G.P.A.	.216	.060					
	.036	.566					
Sex	.050						
	.633						

*Note: The first entry in each cell is *r* (Pearson product-moment correlation) and the second entry is the level of significance. In some instances other types of correlation coefficients would have been preferable but the program used (Statistical Package for the Social Sciences) did not provide same, so *r* is reported for each. The abbreviations used for the variables are: Dept. (physics or no-physics), Form. (formal operations score from the questionnaire), I.Q. (intelligence quotient) and G.P.A. (grade point average). Sum 1 refers to the original judge's scoring and Sum 2, the second judge.

ground subjects. Since there was an immense difference between the two groups (physics vs. no-physics) any sex differences in this study may be confounded with the main effect. No differences were found between the men and the women in the physics group alone (the mean on the abstract conservation tests for the women was 60 and for the men 59).

Also of interest in Table 7 is the correlation between the scores on the abstract conservation problems and those on formal thinking ability from the questionnaire (r = .64). Formal thinking ability has, as reported earlier, good predictor capacities as to abstract conservation ability. As a predictor, it was second to whether or not the subject had physics.

The variables used as predictors together account for approximately 61 per cent of the total variance. Background (physics vs. no-physics) alone accounts for approximately 49 per cent. The questionnaire formal thinking score accounts for 9 per cent of the variance. In accounting for the remainder of the 61 per cent total, I.Q. was shown to be only a slightly better predictor than sex, G.P.A. or age.

An analysis of variance was performed grouping the subjects into four age categories (20 and under, 21-25, 26-30, and over 30) and testing for differences on abstract conservation. No significance was found (see Table 8).

Table 8

Analysis of Variance

Grouping Subjects by Age

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
Between Groups	1076.36	3	358.79	1.366	$p < .258$
Within Groups	23646.92	90	262.74		
Total	24723.28				

Note: Subjects were grouped by age as follows:

Group 1 (18 through 20) N = 56
Group 2 (21 through 25) N = 19
Group 3 (26 through 30) N = 8
Group 4 (over 30) N = 11

The table also gives the number of subjects in each age group. The higher age groups had few subjects compared to the lower age groups, and this should be considered in interpretation of the results. The results of this analysis confirm the regression analysis which suggested that age was not a useful predictor.

The next analysis for main effects was an analysis of covariance, using either G.P.A. or I.Q. as the covariate. Both approaches are shown (see Tables 9 and 10, respectively).

The statistics using G.P.A. as the covariate are significant ($F(1,91) = 84.78$, $p < .001$) as well as those using I.Q. ($F(1,91) = 61.56$, $p < .001$). An analysis of variance breakdown for each of the four abstract conservation problems yields the following F scores: bicycle problem $F(1,89) = 57.42$, $p < .001$; ball bearing problem $F(1,89) = 42.43$, $p < .001$; rock problem $F(1,89) = 17.99$, $p < .001$; and the candle problem $F(1,89) = 61.75$, $p < .001$. These analyses of variance results are summarized in Tables 11 through 15. These results support the argument that the differences found are due more to environmental than hereditary variables.

Technically, the results of the analysis of covariance using G.P.A. as the covariate are more reliable than those using I.Q. as the covariate. As reported above (see Table 7)

Table 9

Analysis of Covariance

Using G.P.A. as the Covariate

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
G.P.A.	1449.65	1	1449.65	10.95	$p < .001$
Amount of Physics	11224.91	1	11224.91	84.78	$p < .001$
Residual	12048.71	91	132.40		
Total	24723.27	93			

Table 10

Analysis of Covariance

Using I.Q. as the Covariate

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
I.Q.	6319.90	1	6319.90	52.39	$p < .001$
Amount of Physics	7426.01	1	7426.01	61.56	$p < .001$
Residual	10977.37	91	120.63		
Total	24723.28	93			

Table 11

Analysis of Variance

for the Bicycle Problem

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
Amount of Physics	745.11	1	745.11	57.42	$p < .001$
Residual	1154.99	89	12.98		
Total	1900.10	90			

Note: The above statistics reflect a pooling of the error terms resulting from all interactions. This analysis of variance considered whether or not subjects received the concrete conservation demonstration, additional sensory feedback and the sex of the subject. These are not listed above and account for the remaining 3 degrees of freedom. The small error terms from these same effects were not made part of the final pooled error term.

Table 12

Analysis of Variance

for the Ball Bearing Problem

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
Amount of Physics	580.01	1	580.01	42.43	$p < .001$
Residual	1216.71	89	13.67		
Total	1796.72	90			

Note: The above statistics reflect a pooling of the error terms resulting from all interactions. This analysis of variance considered whether or not subjects received the concrete conservation demonstration, additional sensory feedback and the sex of the subject. These are not listed above and account for the remaining 3 degrees of freedom. The small error terms from these same effects were not made part of the final pooled error term.

Table 13

Analysis of Variance

for the Rock Problem

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
Amount of Physics	238.42	1	238.42	17.99	$p < .001$
Residual	1179.20	89	13.25		
Total	1417.62	90			

Note: The above statistics reflect a pooling of the error terms resulting from all interactions. This analysis of variance considered whether or not subjects received the concrete conservation demonstration, additional sensory feedback and the sex of the subject. These are not listed above and account for the remaining 3 degrees of freedom. The small error terms from these same effects were not made part of the final pooled error term.

Table 14

Analysis of Variance

for the Candle Problem

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
Amount of Physics	609.38	1	609.38	38.37	$p < .001$
Residual	1413.45	89	15.88		
Total	2022.83	90			

Note: The above statistics reflect a pooling of the error terms resulting from all interactions. This analysis of variance considered whether or not subjects received the concrete conservation demonstration, additional sensory feedback and the sex of the subject. These are not listed above and account for the remaining 3 degrees of freedom. The small error terms from these same effects were not made part of the final pooled error term.

Table 15

Analysis of Variance

for the Combined Abstract Conservation Problems

Source of Variation	Sum of Squares	D.F.	Mean Squares	F	Significance
Amount of Physics	8373.43	1	8373.43	61.75	$p < .001$
Residual	12067.71	89	135.59		
Total	20441.14	90			

Note: The above statistics reflect a pooling of the error terms resulting from all interactions. This analysis of variance considered whether or not subjects received the concrete conservation demonstration, additional sensory feedback and the sex of the subject. These are not listed above and account for the remaining 3 degrees of freedom. The small error terms from these same effects were not made part of the final pooled error term.

I.Q. correlates with whether or not a student has physics (r = .37) more so than does G.P.A. (r = .11). This difference suggests that G.P.A. is the safer covariate. The amount I.Q. influences taking physics courses yields F (1,92) = 1.362, p = .25. This indicates that there is a small interaction between whether or not a student takes physics and that student's I.Q. Eighteen of the 36 physics students, however, were in advanced physics courses so part of that interaction simply indicates that there is a relationship between being successful in physics and I.Q., which is expected. For this reason, both approaches were used. By way of mention, this study found G.P.A. and I.Q. correlate (r = .38, see Table 7).

Sex was reported as showing a significant F score in some of the computer printouts on the analyses of variance and covariance, but is not presented otherwise as a result because it is confounded with the main effect, as discussed above in the multiple regression analysis results.

The interaction between I.Q. and whether or not a student has studied physics was discussed above. With respect to other interaction effects, none were predicted and none were found. Therefore, all two-way and higher interactions were pooled with the residual error terms from the computer analysis to form the error mean squares in the F scores reported above for the analyses of variance.

Inasmuch as all of the analyses show large differences between subjects with physics backgrounds and those without, it should be mentioned that the variance of scores within each group was substantial and no "ceiling effect" is present.

As mentioned earlier, the demonstration of concrete conservation to some subjects did not have an effect as hypothesized. F scores on the abstract conservation problems comparing subjects receiving the concrete conservation demonstration with subjects having no demonstration were not significant. Descriptive statistics relating to this are shown in Table 16. Also of interest is that the sensory feedback that some subjects received by participating in the presentation of the abstract conservation problems was not effectual as hypothesized. The descriptive statistics illustrating this are also in Table 16. As can be seen, particularly in the bicycle problem, the small effect found was in the wrong direction. These findings, i.e., that the original supporting hypotheses were not confirmed, are elaborated in the discussion.

The final analyses looked for the following trends: 1- the amount of physics in a subject's background and whether performance increased therewith, 2- whether performance increased over the number of abstract conservation problems performed and 3- whether performance increased within types of abstract conservation problems

Table 16

Descriptive Statistics of the

Concrete Conservation Demonstration

and Sensory Feedback Effects

Variable	Subjects					
	Physics		No Physics		Total	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Concrete Conservation Demonstration	59.00 N= 17	15.66	36.76 N= 29	12.58	44.98 N= 46	13.72
No Concrete Conservation Demonstration	59.32 N= 19	15.01	35.10 N= 29	13.23	44.69 N= 48	13.94
Sensory Feedback	58.16 N=19	14.49	34.90 N= 29	11.44	44.10 N= 48	12.65
No Sensory Feedback	60.29 N= 17	16.67	36.97 N= 29	14.27	45.59 N= 46	15.16

(over the two types of motion problems and over the two types of heat problems).

For the first trend, the amount of physics in a subject's background (in the instance of this study no physics, one quarter or three or more quarters) makes a difference (see Figure 1). In this case $F(1,91) = 51.42$, $p < .001$.

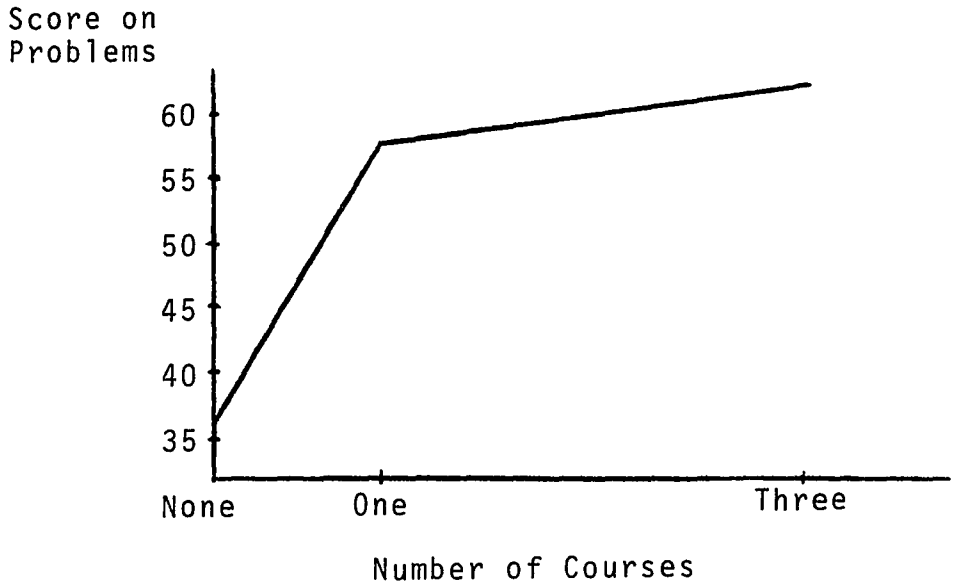
The next trend showed no improvement gained during performance over the four abstract conservation problems. A simple repeated measures analysis of variance showed an $F < 1$ on this measure ($F(3,276) = .40$, $p < .75$.

With respect to the third trend, t-tests performed on both the temperature and the motion problems showed no significance. For the temperature problems the statistic was $t(93) = -.28$, $p < .78$. For the motion problems the value was $t(93) = 1.11$, $p < .27$. These values were not surprising inasmuch as no improvement of performance effect had been found over all four problems, as reported above.

Figure 1

Trend between Number of Physics Courses

and Total Score on Abstract Conservation Problems



Note: Means were as follows: no courses (35.93), one course (57.00) and three courses (61.33). No subjects had two courses.

Discussion

That some adults have abstract conservation abilities and others do not was sustained by the results of this research. Not only is that affirmative of the main hypothesis (see Abstract) but it also carries the implication that this difference is experiential. If it were mainly maturational it would imply either that this ability comes later in adulthood than was representative by the subjects or that something did not occur in the maturation of the no-physics background subjects that did occur in the physics students. Inasmuch as 11 of the subjects herein were over 30 (see Table 1 in the method section) and that both physics students in this group did demonstrate abstract conservation and that seven of the nine no-physics background students did not, it appears that later maturation is not a realistic explanation. Perhaps research of this nature should be continued using many different age groups to confirm this. The other approach, that something different occurred in the development of the physics students, would suggest either an interaction effect or a purely experiential effect. In both cases experience is implied and that is the point of the corollary of the main hypothesis. Thus the suggestion that the difference is experiential is also sustained.

The supporting hypotheses, that instruction is con-

crete conservation problems and that increased sensory feedback during the presentation of the abstract conservation problems would make differences in performance, were not upheld. There are two reasons that come to mind for this occurrence. The first is that the treatments in both cases were not sufficient to make a difference. It may be that increased emphasis in both the length of time devoted to these variables and in how the variables are introduced would in future research sustain that experiences of these types would make differences in performance. The other reason is that these types of experiences are unrelated to abstract conservation. With respect to the sensory feedback, the design of the problems was simple and the subjects all saw and heard the same effects. The subjects who participated in the performance of the tasks did get cutaneous feedback that the non-participant did not receive. It is reasonable to suggest that the cutaneous sense is not the most discriminative of the human senses and that the design should have offered visual and hearing feedback, in addition to cutaneous feedback, for some subjects and not for others. Having some subjects view the demonstration of the abstract problems through a window and at a further distance from other subjects may have increased this effect. Another approach could have some subjects see the actual problems and others view only a film of

what was done. More research could investigate these possibilities. As it happened, these experiences were either too weak or not at all related to abstract conservation. Inasmuch as other experiences, such as having exposure to physics instruction, makes a difference, regardless of intelligence, it is reasonable to attempt to conjure other types of feedback and instruction which would also prove effectual.

It is interesting to note that the students studying physics did not have the same teachers. Whether or not this has an effect should be investigated in future research. In this study, however, it appears that there is some factor in exposure to physics as a general topic that makes a difference. Additional types of problems that specifically focus attention to different variables that may be crucial to the development of abstract conservation should also be investigated further. Perhaps types of problem solving that are motor, rather than conceptual, would also reveal certain contingencies. It is my impression that the sensory feedback effect would be the most promising to follow through in future research.

With respect to the entire experimental procedure and the collection of all data necessary, everything went smoothly and no major difficulties occurred which required an alternation in the experimental design. The questionnaire was designed to measure both concrete oper-

ations and formal operations skills and as it resulted only the score involving formal operations abilities was used. It may have been useful to have introduced the other part of the questionnaire score as a predictor in the regression analysis, but such was not done at the time.

With respect to the main effect of abstract conservation skills appearing strong in some adults and not in others, some remarks of what can be learned from the different types of analyses performed are in order. Why the various analyses were used is also included in the following.

In dealing with pioneer research it is best to approach measurement from both discrete and continuous methods of analysis, particularly if there is some question as to the nature of what is to be measured. The first measure used, therefore, was chi-square. This was significant. Inasmuch as the difference appears to be a learned difference, and most learned skills are continuous, it follows that parametric techniques were also used. The three main approaches were regression analysis, analysis of variance and analysis of covariance.

The multiple regression analysis used physics background as the main predictor, supported from the chi-square results. The other predictor variables were, in order of strength, questionnaire score, I.Q., sex, grade point

average and age. Specific details of these predictors appeared in the results section. Comments here are directed to why this order of strength of prediction occurred and the implications thereof. Evidently experience in physics generalizes to develop abstract conservation abilities as tested by problems dealing with energy. This also clearly questions maturation as the resource for this skill. Intelligence also, at least as measured by I.Q., is a poor predictor by comparison to physics background. The second strongest predictor was the questionnaire score. This score also correlates with physics background (r = .57) and is an independent measure of formal operations abilities in addition to the abstract conservation problems, which are indicative of at least this level of thinking if not indicative of a more advanced stage. This is important because the design of the problems, dealing with conservation of energy, could otherwise favor only the physics students and no argument would exist to establish abstract conservation as a special type of cognitive skill in its own right.

I.Q. is a better predictor than G.P.A., but only slightly. Of course, I.Q. is an organismic variable and is a more stable measure than G.P.A. This probably accounts for its slight advantage as a predictor. Sex is somewhat confounded with physics background because of the sex distribution of the subjects. This was discussed

in the results section. Therefore its contribution as a predictor is not well established. Age had no significance as a predictor in this study. Of course all subjects were over 18. If younger subjects had been used as well, this would in all likelihood change. Also it would have been useful to have had more subjects over 30 available. A longitudinal study mapping the on-set and full development of abstract conservation would add certainty and more definition to this skill.

Finally, it is notable that all the F-scores for each predictor, when figured separately from the other predictors' contributions, were significant in their own right, with the exception of that for age. The homo-scedasticity of these subjects with respect to age is responsible for this.

In all, the regression analysis did account for over 60 per cent of the variance. Future research should be able to add additional variables to help account for even more. One such variable mentioned above that was over-looked, the questionnaire score on concrete operations, may have been helpful. Experiential variables, such as amount of education, may also be helpful. These were better predictors in the present research than those of an organic or maturational nature. Inasmuch as age did not contribute much as a predictor, it is not surprising that an analysis of variance performed by grouping age

categories was also unfruitful. Nothing additional was learned thereby.

The problems designed to test abstract conservation seemed to have some variation in difficulty, although not a tremendous amount. As shown in Table 4, the means for the bicycle problem are the lowest and those for the candle problem the highest. The rock problem yielded the lowest F-score in the analysis of variance proceedings. This, however, was still significant at the .001 level of confidence. Small variations in the understanding of the various forms of energy probably account for these differences. Future research could clarify these differences further.

The analysis of covariance designs were chosen in preference to blocking for several reasons. The most important measure to control for the purposes of this experiment was I.Q. The number of subjects having physics experience was limited and grouping them by I.Q. would have left very few subjects in some categories. It was felt that the experimental groups were already fairly homogenous and that the large variances usually eliminated by blocking procedures were already controlled by either elimination or the constancy of the experimental conditions. The analysis of covariance seemed an appropriate way to statistically control for precision. From all appearances the assumptions for an analysis of co-

variance were met. The large F-scores obtained vindicate that the error term was indeed controlled enough to grant more than sufficient power for the needs of the experiment.

Organismic variables are well-suited for use as covariates inasmuch as treatments should not have too much of an effect thereon. In planning this research, as mentioned above, I.Q. appeared to be an excellent covariate and also needed to be controlled in some manner to test whether or not abstract conservation was basically a learned skill. It was decided to have information available on a second possible covariate, one not unrelated to intelligence, and grade point average was such a choice. It was not known at the time how strongly I.Q. would correlate with taking physics. As mentioned in the results section, the analysis of covariance using G.P.A. as the covariate better meets the requirement that the covariate not correlate too much with the criteria used in forming the experimental groups. I.Q. is, however, a reliable and stable statistic so both analyses of covariance do contribute. Correlations related to this are given in Table 7, and the statistics presented in the results section.

Another reason for using blocking is to give increased information on interaction effects. Inasmuch as no interaction effects were expected this was further

reason to let the covariance analyses suffice for the purposes. The non-prediction of interaction effects was upheld in the analyses of variance performed on the separate and combined scores of the abstract conservation problems. All two-way and three-way interaction effects contributed very little to the F-scores when pooled with the residual error term in each case.

All of the above results, i.e., chi-square, regression analysis, analyses of variance and analyses of covariance were consistent. They all support the main hypothesis and also show experience to be the important factor.

The trend shown by the amount of physics experience in a subject's background is interesting, but also expected from what is shown throughout the other analyses. The significant difference between having physics and developing abstract conservation skills is notable. The amount of physics experience also makes a predictable difference.

Only one physics student failed to show adequate ability in this respect. The total points possible on the abstract conservation problems was 80. The combined score on the abstract tests was less than 40 for this student, who had only one quarter of introductory physics. Five of the 36 students with physics backgrounds scored between 40 and 50 and four of these had only the intro-

ductory, one-quarter, physics course designed for non-physical science majors. Therefore, the effect was very close to being clean cut, right across the board. One would expect a trend to be evident and it is. This suggests the teachability of abstract conservaton and gives further emphasis to experience, as it is related to physics instruction. It is evidently a continuous, rather than a discrete measure. As was mentioned in the results section, however, there was sufficient variance to show that no "ceiling effect" was operating.

It is surprising, in view of the above, that no improvement during performance over the four types of abstract conservation problems was found. It appears that the concept of abstract conservation is strong enough once physics is taken that the completion of the four simple problems designed for use herein was not important. This effect may have appeared if a much larger sample had been available. Only five to ten subjects were represented in the problem presentation orders. Small effects may have become masked. It is also possible that the problems were too similar to show generalization from one to another. If more complex abstract conservation problems were designed to follow simpler problems, and more problems used per subject, a generalization effect would in all likelihood emerge. One would expect this from an experientially determined skill.

With respect to the design of the abstract conservation problems, the extension of the usual conservation problem paradigm was successful. The problems were easy to administer and score, and the design of the equipment was easily accomplished with minimum cost. The results obtained from this basically simple approach do support the position that an advanced type of conservation skill has been identified and measured. This operational definition of abstract conservation is in itself a small contribution to a very large field of data now amassed on conservation. Much of these data show that conservation skills on many lower levels are very much tied into maturational, as well as experiential, variables. The data herein suggest that abstract conservation is representative of a type of conservation that is dependent on learning, and that it occurs later than other conservation skills. Perhaps another step in a conservation skill hierarchy has been defined. Other approaches of measurement and more research may sustain this.

If an addition has been made to the conservation skill hierarchy, does this imply that an addition may have been made to stage theory in general, with respect to cognitive development? As mentioned in the introduction, several researchers have suggested recently that there is a possibility that more stages exist. Abstract conservation is an advanced skill that may belong to such

categories. It is, however, only an operational measure that is at best representative of only one aspect of such a stage, rather than the stage itself. Cautious interpretation is required. The uncovering of this part-of-the-whole does invite more research, however, and suggests that such a stage or stages may exist. The crucial question is whether or not abstract conservation is a qualitatively distinct ability and not just a quantitatively advanced part of formal operations as espoused by Piaget. Another consideration is whether or not holding to the quantitative-qualitative criterion in judging additional stages is a good idea. Until more work can be done on a comparative basis identifying what other differences may exist between abstract conservers and non-conservers this will have to remain an open question.

Abstract conservation may be only a quantitative advancement that is learned or it may indicate a type of highly abstract capability only obtained by a few adults. Arlin (1975) claims that only 50 per cent of adults reach Piaget's formal operations stage. How many advance further? Do these few represent a qualitatively distinct manner of thinking?

Another consideration, the same crucial question raised by Deutsch (1937), is whether or not stage theory is the best matrix to apply to any explanation of cognitive development. Piagetian stage theory represents

biological-maturational changes in structure. Kohlberg (1973) suggests that socio-cultural or environmental stages that consist of personality roles is an alternative approach that is valid in moral development and may be so with respect to cognition. Such an approach is experience related and does not necessarily imply the same assumptions as maturational stage theory. Kohlberg continues stating that individuals solve problems at the highest levels available to them. Arlin (1975) claims to have identified a "problem-finding" stage that is suggested to be higher than Piaget's formal operations. Although abstract conservation may not represent in itself a qualitative change, does the thinker who has this skill use a logical approach to problems that is qualitatively different from thinkers who do not have this skill? Kohlberg (1973) challenges students of cognitive development to find structural changes that result from experience. He states that it is unlikely that adults have maturational stages, but feels that some structural changes do not necessarily presuppose maturation as a prerequisite. Since abstract conservation is so clearly experiential, it may serve as a key to this line of reasoning. If this is so, the basis for demonstrating the existence of more stages to cognitive development could be close at hand. Can structural changes arise through experience? This would constitute more than a quantitative change. Is the highly creative and inventive mind

using no more than formal operations? Gruber (1973), as mentioned in the introduction section, suggests that this type of thinking is representative of a higher level of development.

Piagetian theory emphasizes maturation, and in so doing may be an invalid matrix to help answer the above implications. Furthermore, it may be too rigid to insist that only great qualitative differences can support the argument of another stage. That may be true of a biologically based theory, but not true of a culturally or experientially based approach. Cognitive advancement does occur in adulthood and another skill has now been added to investigate further.

Another approach upon which to argue additional stages is based on sequencing. Certainly an additional sequence in the list of types of conservation that occur during cognitive development from infancy onward, in a given order, has now been defined. How many sequences can be lumped together in one stage? Types of conservation represent all levels of all stages of cognitive development. Now we are dealing with a highly advanced form of conservation. Are we dealing with a highly advanced stage, yet undefined?

Still another question involves critical periods. Is there a critical period for learning abstract conservation? This is not known. However, inasmuch as many

adults did not exhibit same, will they be able to learn this later on? This poses yet another reason to leave the question concerning additional stages open at this point. If a critical period can be determined, would this not suggest an experientially-based structural change in the instance of abstract conservation? If this skill is only quantitative, then it should be teachable at any age. If not, then perhaps this is evidence of some structural capacity that cannot be changed after the correct developmental timing is passed. Physics teachers may yet be delighted to find out how essential a physics experience may be!

In review, the solution is couched in yet undone work. Future research needs to be done with a greater number of subjects per experiment, utilizing alternative experimental designs. It needs to be conducted on both younger and older subjects than represented herein. The teachability of abstract conservation skills needs to be defined further, specifically delineating what experiences that physics knowledge represents are the particular reasons for this ability. Longitudinal studies are implied as well as comparative studies of various types of professional adults to determine how limited or wide spread abstract conservation is.

This research is pioneering. As usual it poses more questions than it answers. Application to broad popula-

tions must be cautious. I have been speculative, but only in the interest of being heuristic. Ziman (1969) appropriately summarizes this contribution:

> A regular journal carries from one research worker to another the various . . . observations which are of common interest. . . . A typical scientific paper has never pretended to be more than another little piece in a larger jigsaw--not significant in itself but as an element in a grander scheme. This technique of soliciting many modest contributions to the store of human knowledge, has been the secret of Western science since the seventeenth century, for it achieves a corporate, collective power that is far greater than one individual can exert (p. 318-324).

Appendix I

Questions on Abstract Conservation Problems

The following questions are distributed on a response sheet at the time each problem is concluded (one response sheet per problem). The instructions that appear on each sheet are also shown. If the student asks for clarification, the same is given by repeating verbatim the question and if needed by defining briefly any word the student doesn't understand, using synonyms where it appears necessary. The Piagetian method of using prompting and explanation is applied. The object is to get the student to answer all the questions to his own satisfaction so that some evidence of the subject's manner of thinking is revealed. The student will complete each problem and the written answers to the questions thereon before the next problem is presented.

Instructions

Write down the answers to the following questions. Give as complete an answer as you can so that the way you think about each problem is easily understood. If you do not understand a question or a word, be sure to ask for help.

Problems

Rock Problem

Name the variables that are involved in the experiment.

What happened to the heat in the rocks during the experiment?

Which variables changed the most during the experiment?

Which variables changed the least or did not change at all during the experiment?

Candle Problem

Name the variables that are involved in the experiment.

What happened to the heat from the candle after the jar was placed over the candle?

Which variables changed the most during the experiment?

Which variables changed the least or did not change at all during the experiment?

Bicycle Problem

Name the variables that are involved in the experiment.

What happened to the motion that was in the wheel?

Which variables changed the most during the experiment?

Which variables changed the least or did not change at all during the experiment?

Ball Bearing Problem

Name the variables that are involved in the experiment.

Why did the ball stop? Why didn't it keep rolling upward?

Which variables changed the most during the experiment?

Which variables changed the least or did not change at all during the experiment?

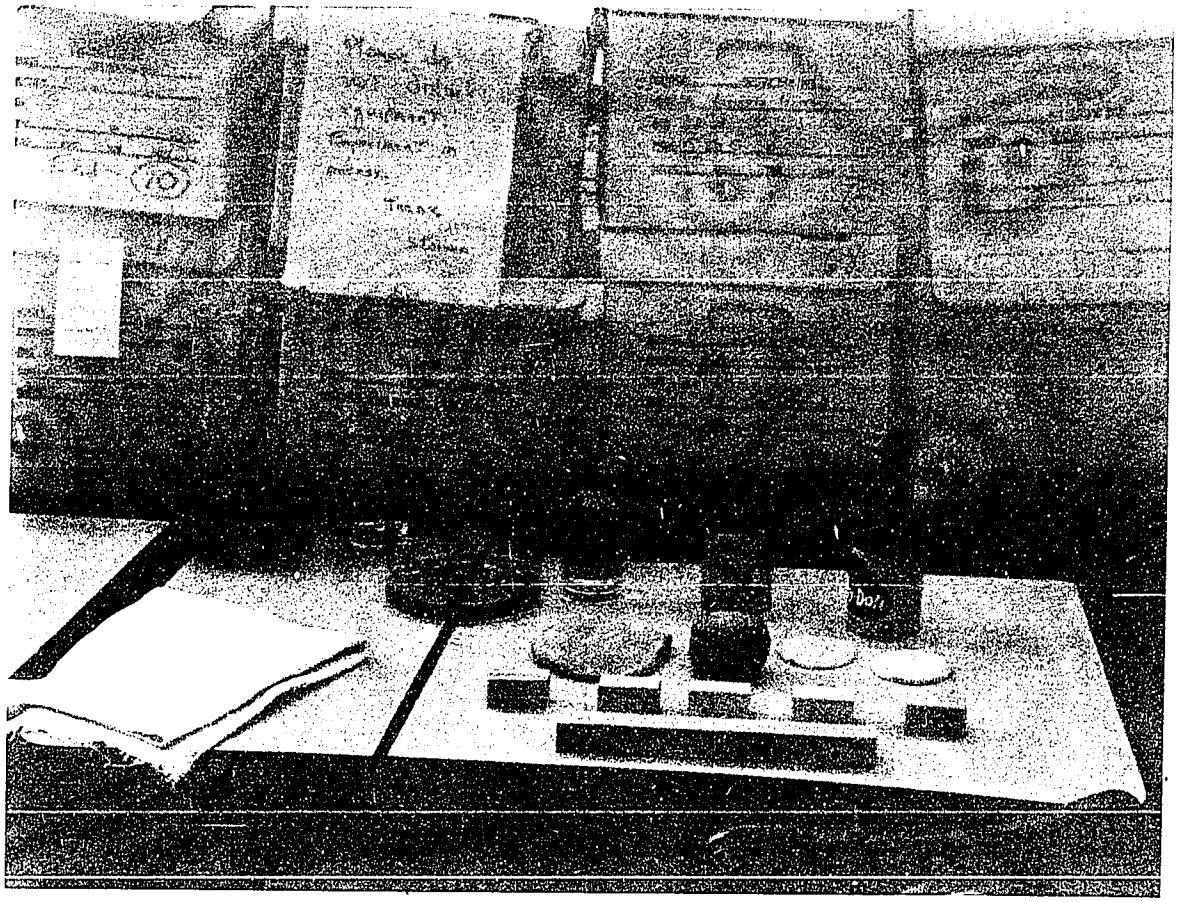
Scoring

One point is given for each variable mentioned that is correct in the first question up to a total possible for

this question of five points. Variable points, up to ten, are given for the second question depending on how well the abstracted variable is accounted for. Up to two points are given for rudimentary answers that do not attempt to conserve. Up to five points are given for answers that imply conservation but do not clearly support same or that show conservation but incorrectly account for it. Up to eight points are given for answers that show and explain conservation in at least one correct manner for the problem. Ten points are given if conservation is explained in two or more ways for the problem. The second question is the most important of the four questions in each instance. The other questions will give additional information to help the judges understand the level of conservation that occurs in each experiment. One point is given for each variable mentioned that did change the most and that did change the least during the experiment. The answers that are correct in each instance are determined before the experiment and the responses objectively scored on the mentioning of same. The total combined points allowed for questions three and four is five. This is to give both these combined questions not more weight than the first question. These questions were included as a follow-through in case the individual understood some variables but failed to mention same in the first question.

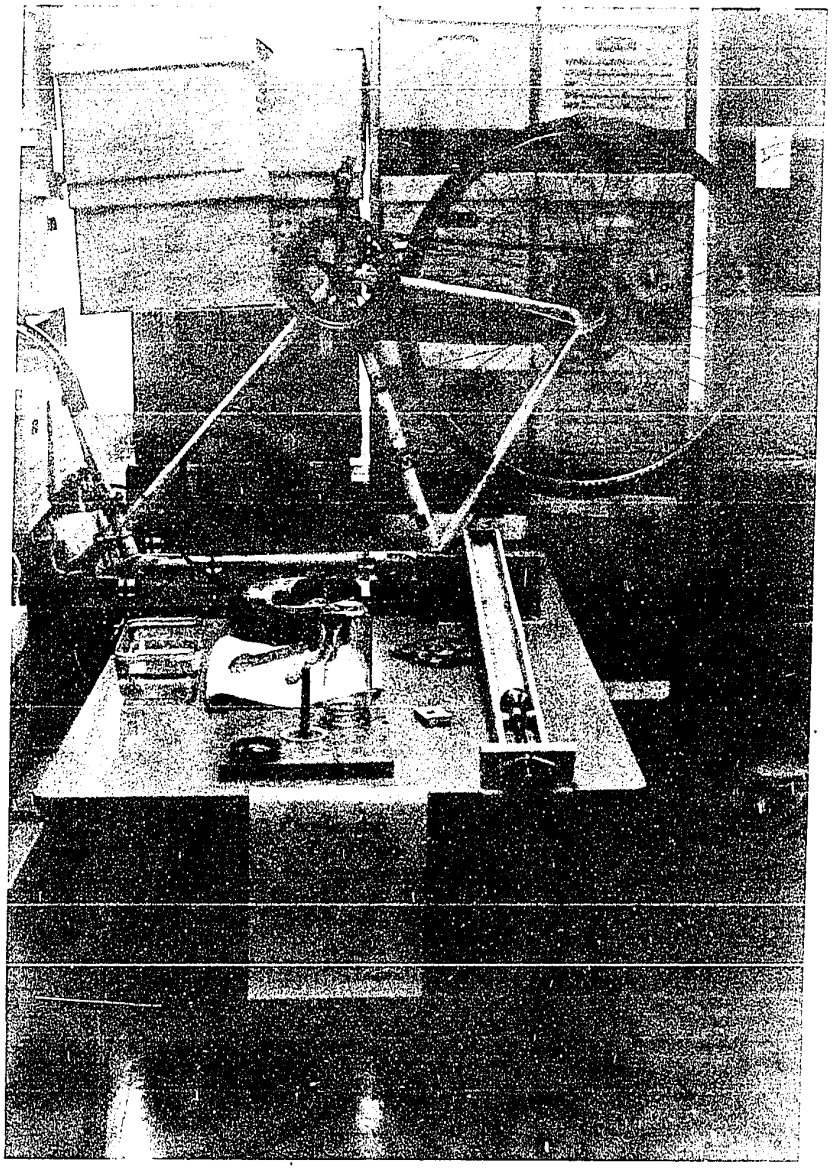
Appendix II

Photographs of Equipment



Photograph I

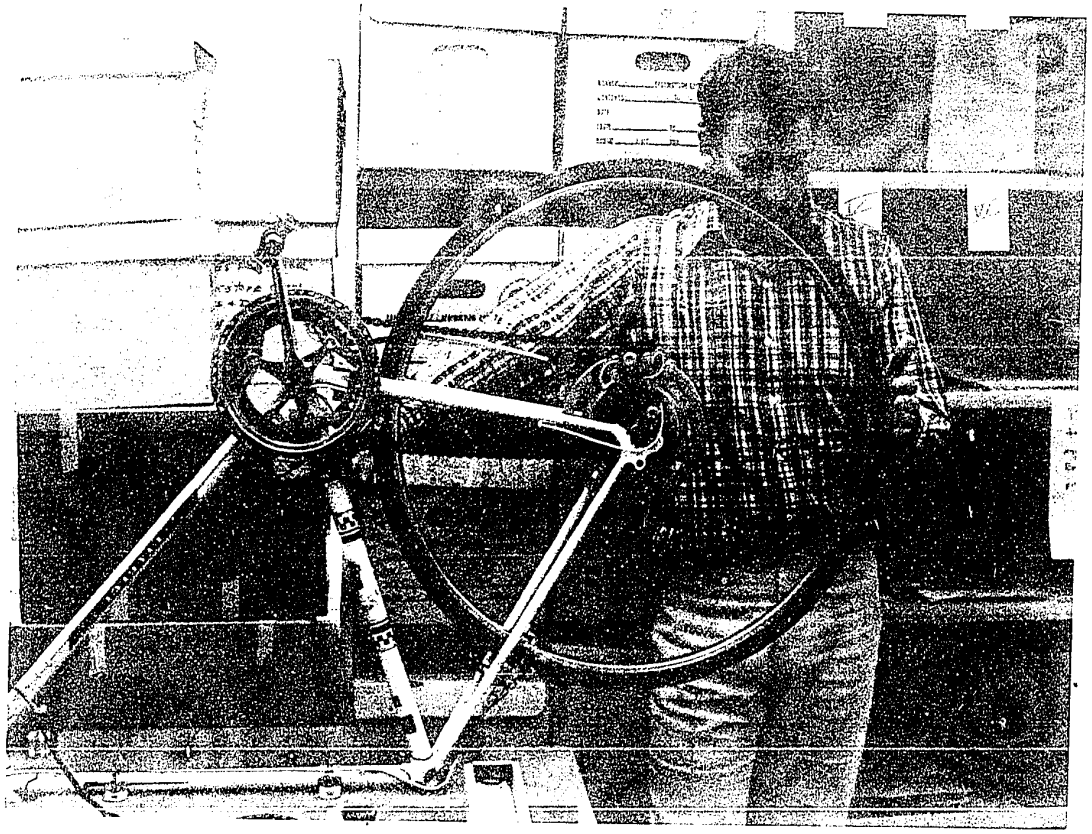
Materials used in the Concrete Conservation Demonstration on Mass, Length and Volume



Photograph 2

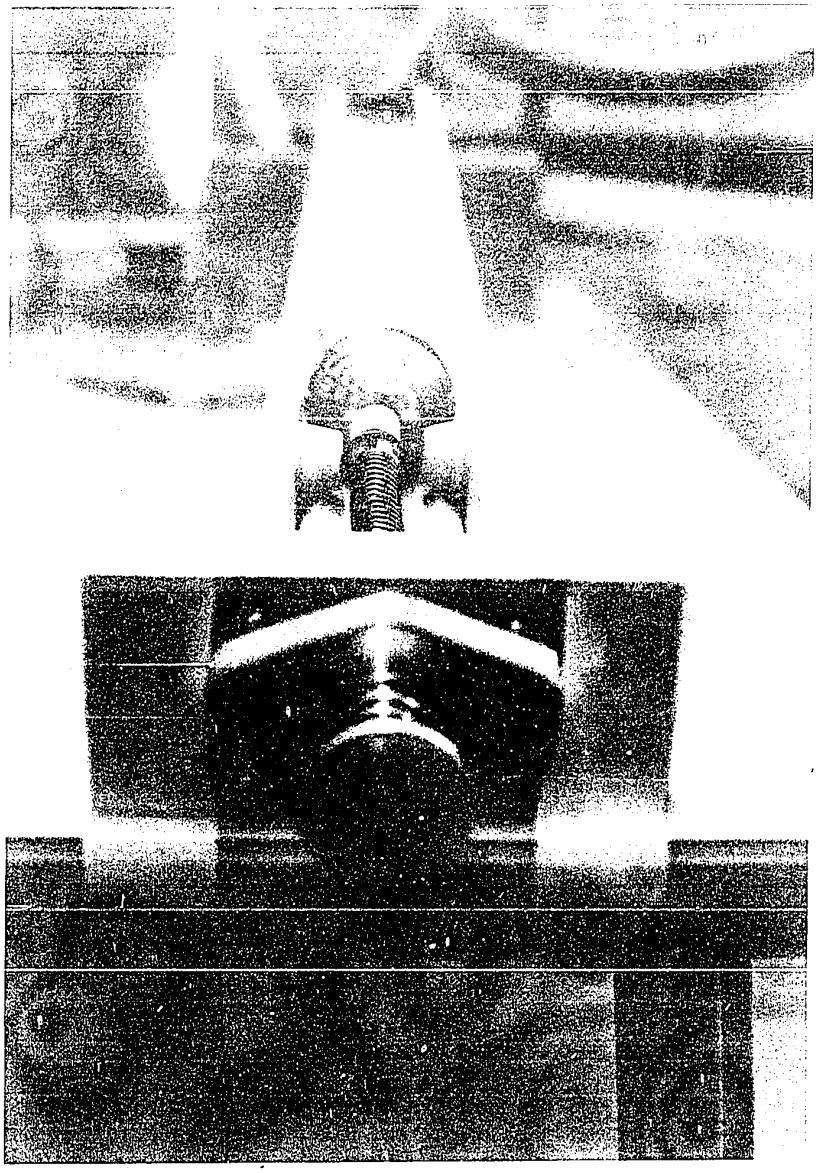
Materials and Apparatus for the

Abstract Conservation Problems



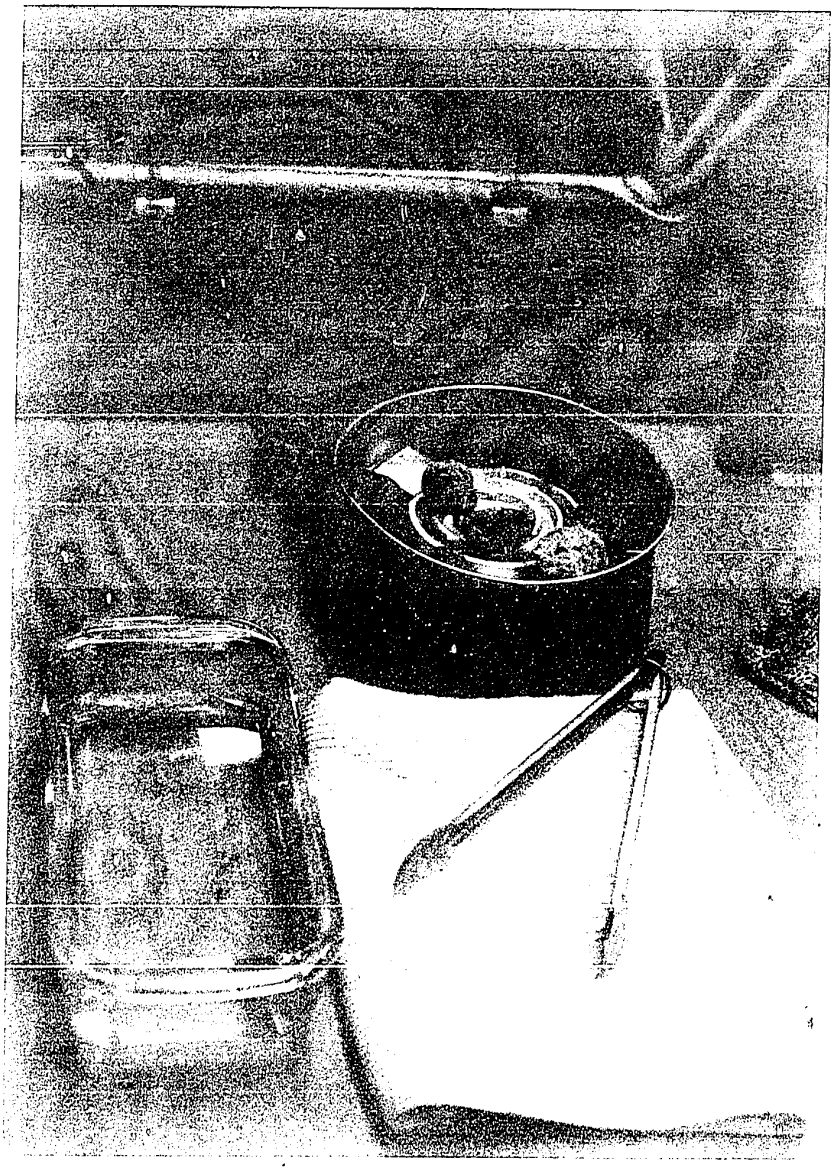
Photograph 3

Apparatus for the Bicycle Problem



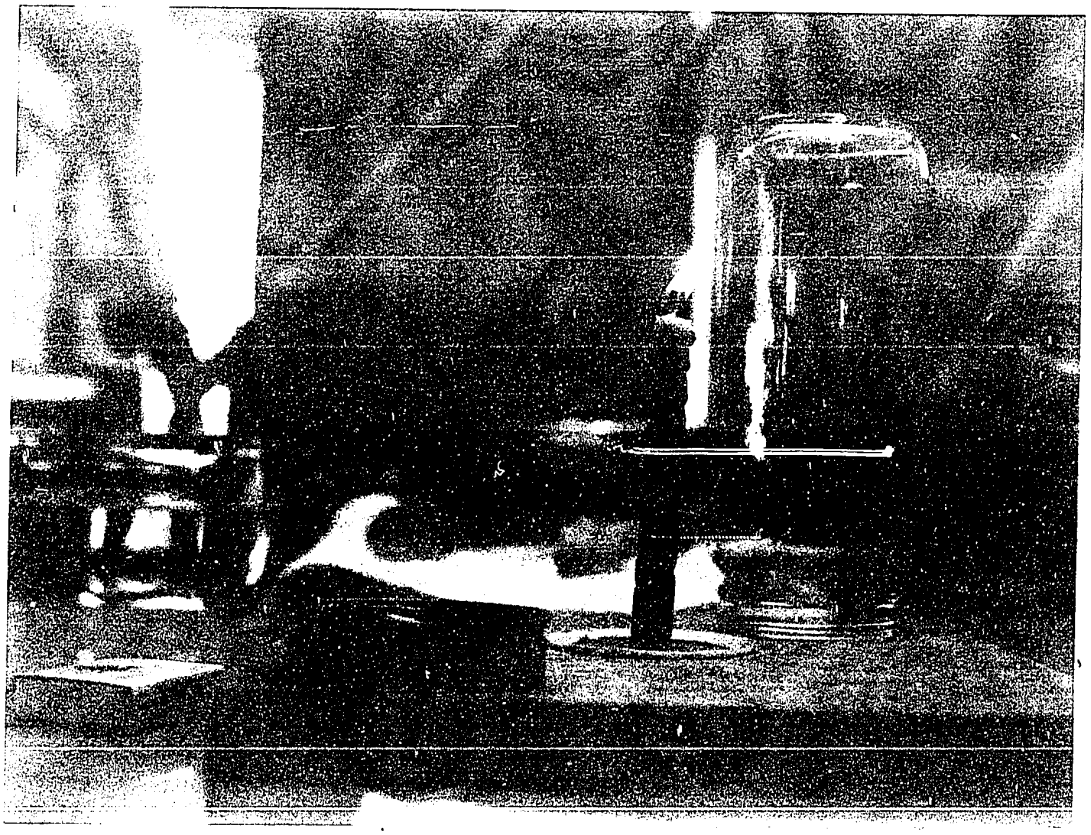
Photograph 4

Apparatus for the Ball Bearing Problem



Photograph 5

Apparatus for the Rock Problem



Photograph 6

Apparatus for the Candle Problem

Appendix III

Demonstration of Concrete Conservation

The following is an outline of a presentation that follows the Piagetian method of demonstrating these simple conservation tasks. In each instance and for all questions asked the experimenter either verbally confirms that the subject's answer is correct or else supplies the correct answer.

I Conservation is defined as the ability to identify variables before, during and after changes in them may occur. It implies the ability to account for the variables at any time. (For students who had trouble understanding what a variable is it was simply defined as a factor that can have an influence on how something turns out.)

II Conservation is demonstrated as follows:

A- Conservation of Mass

1- Two equal balls of clay are shown.

2- One is flattened into a pancake and the subject is asked if the amounts are still the same.

3- The subject is asked how he would prove they are the same and reversibility is demonstrated by forming the pancake back into a ball.

B- Conservation of Length

1- Two rows of wooden blocks are shown parallel to each other and each row is the same length.

2- The blocks in one row are spaced out so that the row is longer if the spaces are counted. The subject is asked if there is still the same amount of wood in each of the parallel rows.

3- The subject is asked to prove that they are the same and reversibility is demonstrated by putting the blocks back together with no spaces between them.

C- Conservation of Volume

1- Two containers which are alike are shown and the subject is asked to fill each of them with colored water so that each has the same amount.

2- Water is transferred from one container into a different type of container and the subject is asked if each container then has the same amount of water.

3- The subject is asked how he would prove they are the same and reversibility is demonstrated by pouring the water back into the similar container.

Appendix IV

Questionnaire on Operational and Formal Thinking

1- What makes the wind blow?

2- What makes frost on the windows in Wintertime?

3- Why do balloons sometimes go up in the air?

4- Why do boats float on top of the water instead of sinking?

5- What causes thunder?

6- Some Freshmen play tennis.

All tennis players do well in school.

Conclusions:

A- All freshmen do well in school.

B- All freshmen do poorly in school.

C- There are freshmen who do poorly in school who are also tennis players.

D- There may be freshmen who do well in school who are not tennis players.

E- The freshmen who are not tennis players do poorly in school.

Explain your choice.

7- Some woozles are warm blooded.

All whatchits are warm blooded.

A womuk is warm blooded.

Conclusions:

A- the womuk is a whatchit.

B- The womuk is not a whatchit.

7- (Continued)

C- The womuk is a woozle.

D- The womuk is not a woozle.

E- The womuk may be a whatchit.

Explain your answer.

8- A black dog is more agile than a white dog.

A brown dog is more agile than a black dog.

Conclusions:

A- The black dog is the most agile of the three dogs.

B- The brown dog is the most agile of the three dogs.

C- The black dog is the least agile of the three dogs.

D- The white dog is the most agile of the three dogs.

E- One cannot know which is the most agile dog of the three dogs.

9- If you are going to go swimming, then it is nice weather.

If you are going boating, then it is nice weather.

You are going boating.

Conclusions:

A- It is nice weather.

B- It is not nice weather.

C- You are going swimming.

D- You are not going swimming.

10- If a squeezle creeps, then a bassly sneaks.

A bassly sneaks.

Conclusions:

A- A freezlo peaks.

10- (Continued)

B- A squeezle creeped.

C- A squeezle may creep.

D- A squeezle doesn't creep.

E- A bassly doesn't sneak and a squeezle doesn't creep.

Explain your choice.

11- If there are more yellow rugs than blue rugs and less green rugs than blue rugs, which rugs are in the greatest quantity? Explain your answer.

12- Deciduous trees lose their leaves.

Non-deciduous trees do not lose their leaves.

Non-deciduous trees are evergreens.

Are there more evergreens than trees? Explain your choice.

13- If ducks are birds and eagles are birds, are there more ducks than birds? Explain your answer.

14- To make Kool-Aid one mixes three ounces of Kool-Aid mix with a pint of water. How much water needs to be added to fifteen ounces of Kool-Aid mix in order to make Kool-Aid?

15- A man has identical pieces of lead and identical pieces of iron and uses them to weigh bricks. He finds that 10 bricks weigh 3 pieces of lead and 7 pieces of iron. If 20 bricks weigh 7 pieces of lead and 3 pieces of iron, how many pieces of iron will weigh the same as one piece of lead?

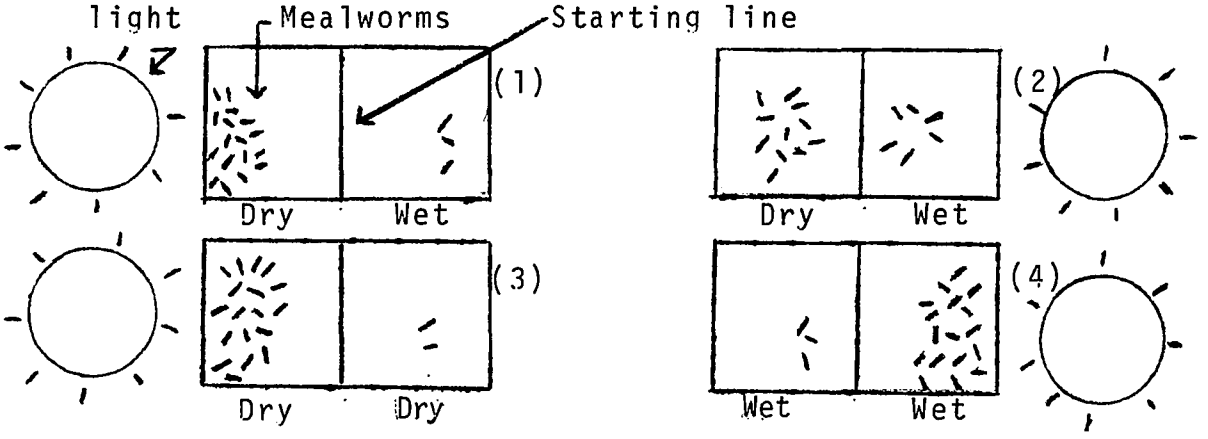
16- At a certain grocery store there are twice as many oranges as there are apples. If one out of every four oranges and one out of every three apples are rotten, are there more rotten apples than rotten oranges in the grocery store? Explain your choice.

17- If a car travels 60 miles in an hour or 88 feet in a second, how many feet in a second will another car travel if it is moving 30 miles in an hour?

18- The first garage holds 25 vehicles; there are 5 trucks and 20 cars there now. The second garage holds 55 vehicles; it is now filled with 11 trucks and 44 cars. The third garage holds 35 vehicles, with 7 trucks and 28 cars in it now. Unknown to the drivers, each garage has a "Lucky Parking Spot," where a parking fee is not charged. In which garage is it most likely that a truck is parked in the lucky spot? Explain your answer.

19- A child measures a stick with paper clips. He finds that the stick is 5 large paper clips and 6 small paper clips long. He also finds that another stick half as long as the original stick measures 3 large paper clips and 1 small paper clip long. What is the measurement of a large paper clip in terms of the small paper clips?

20- An experimenter wanted to test the response of mealworms to light and moisture. To do this he set up four boxes as shown in the diagrams below. He used lamps for light sources and watered pieces of paper in the box for moisture. In the center of each box he placed 20 mealworms. One day later he returned to count the number of mealworms that had crawled to the different ends of the boxes.



The diagrams show that mealworms move to or move away from:

A- Light but not moisture.

B- Moisture but not light.

C- Both light and moisture.

D- Neither light or moisture.

Explain your choice.

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