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ABSTRACT

Investigated, within a Piagetian framework, was the degree of abstract preferences exhibited by five different grade levels of science students as they completed eighteen problem solving tasks. Three hundred twenty-nine randomly selected students from five grade levels, ranging from eighth grade to college seniors, were given the Shipley Test of Abstract Reasoning. Groups of concrete and formal operational students were identified as were groups based on sex and grade level. Solutions for each task were ranked according to degree of abstraction represented. Correlations were completed to determine, for each group, the relationship between abstract ability and abstract preferences. Older groups demonstrated greater abstract reasoning ability. No significant differences were found between grade levels with respect to abstract preference scores. This study supported the assumptions that a student's level of reasoning is often below his capacity and that a student's preference toward a specific solution may, in part, be responsible for his below-capacity functioning. (LS)

A STUDY OF ABSTRACT PREFERENCES IN PROBLEM SOLVING TASKS

AND THEIR RELATIONSHIP TO

ABSTRACT ABILITY AND FORMAL THOUGHT

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OBJECTIVES

This study examines the assumption that the level of reasoning used by students when solving problems is substantially below the student's capacity. This assumption is behind the research reported by Raven[1], and he states that the acquisition of Piaget's logical operations and science concepts can be facilitated through instruction. The purpose of this paper is not to refute this finding, but rather, to examine other variables besides the acquisition of logical structures which may effect the capacity at which a student is operating. Specifically, this study was designed to investigate abstract preferences in 18 problem solving tasks and the relationship between these preferences and various cognitive levels of development.* In addition, the effects of grade level, sex, and academic major were examined in relationship to the student's abstract preference scores.

The problem was examined in terms of the following null hypotheses:

1. There is no significant difference in the cognitive level of development for college science students who are science majors and college science students who are non-science majors.

2. There is no significant difference in the abstract preference scores for college science students who are science majors and college science students who are non-science majors.

3. There is no significant difference in the cognitive level of development of students in grades 8, 9, 12, 13** and 16.**

4. There is no significant difference in abstract preference scores of students in grades 8, 9, 12, 13, and 16.

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*In this study, the terms, "abstract ability" and "cognitive levels of development" are used almost interchangeably. The reason for this broad definition of terms is due to the manner in which the concrete operational, formal operational, and transitional sub-groups were formed. A more detailed explanation occurs in the discussion.

**Grades 13 and 16 refer to college freshmen and college seniors, respectively.

In addition, the following research question was examined:
Is there a correlation between abstract preferences in selecting methods to solve problems and cognitive level of development?

DESIGN

Four hundred sixty-six subjects were in a pilot study* which was designed to investigate abstract ability and abstract preferences in college freshmen. The subjects were enrolled in either a general chemistry or a physical science course at a Western Pennsylvania University. All students were administered the Shipley Test of Abstract Reasoning [2] and an abstract preference survey.**

The Shipley Test of Abstract Reasoning is part of a scale for measuring intellectual impairment and it is specifically designed to separate children of different abstraction ages. It is composed of twenty items, may be administered in 10 minutes, and the reliability coefficient obtained for 322 individuals was 0.89.

The preference survey was developed by the authors and is an initial attempt designed to provide an abstraction score for each individual completing the survey. The survey presents 18 written problem solving tasks and requires the subjects to state their preferences concerning methods for arriving at a solution to each task. The methods of solution for each task were ranked by a panel of educators according to the degree of abstraction represented, thus allowing an abstract preference score

*The pilot study was conducted by Mr. Thomas Maduskuie, a student at Indiana University of Pennsylvania.

**A copy of this survey is included in the appendix.

to be calculated. Test-Retest reliability for 18 people was 0.68.

Using the student's academic major as the criterion, the subjects were divided into science and non-science groups. Further, based upon content emphasis, the science majors were subdivided into the following three categories: chemistry, biology, and natural science. Statistical tests and inspection of each category and subcategory were conducted to investigate the relationship between abstraction ability and abstract preferences.

Results from the pilot study stimulated the need to examine this relationship at several grade levels as well as by sex and cognitive ability groupings. Therefore, several classes from five different grade levels ranging from 8th grade to college seniors were randomly selected, and a sample size of three hundred twenty-four science students resulted.

As in the pilot study, each student was given the Shipley Test of Abstract Reasoning and the abstract preference survey. For each grade level, relationships between abstract ability and abstract preference could be examined. Further, it has been shown that the Shipley Test of Abstract Reasoning can be used to separate children into groups that at least approximate the formal, transitional, and concrete stages of development as defined by Piaget.[3] Therefore, on the basis of the Shipley scores, three subdivisions were made for some of the grade levels and again the relationship between the student's abstract ability and abstract preference was examined. Finally, for some grade levels, subgroups were formed on the basis of sex. These subgroups were also examined with respect to abstraction ability and abstraction preferences.

DATA

The data generated by the above design provided an opportunity to examine the relationship between cognitive level of development and abstract preference in selecting methods for problem solving. When comparing several grade levels (Hypotheses 3 and 4), the group means for abstract ability (cognitive level of development) as well as the group means for abstract preferences were tested by using standard analysis of variance techniques. Since the sample sizes were unequal, data were randomly discarded and the Cochran test for equal variances was used as described in Marascuilo.[6]

T-tests were used to compare science and non-science majors (Hypotheses 1 and 2) with respect to their cognitive level of development and abstract preferences.

Subgroups were formed using sex, grade level, academic major, and abstract ability as the criteria. Product-moment correlation coefficients were calculated for each subgroup to examine the general research question.

RESULTS

A comparison between science and non-science majors at the college freshman level was conducted with respect to their abstract ability scores and their abstract preference scores. From Table 1, it may be seen that there is no significant difference in their abstract ability scores; however, a significant difference is indicated in their abstract preference scores. When product-moment correlation coefficients were calculated, it was found (Table 2) that neither the science majors nor the non-science majors showed a significant correlation between abstract ability and abstract preferences.

TABLE 1 — A Comparison Between Science and Non-Science Majors at the College Freshman Level With Respect to Abstract Ability and Abstract Preferences Scores.

Group	n	$\bar{X}$	s	t
		Abstract Ability		
Science	200	17.66	1.62	0.85
Non-Science	266	17.80	1.94	
		Abstract Preference		
Science	200	8.18	1.90	3.83*
Non-Science	266	7.49	1.95	

$*p < .001$

TABLE 2 — Product-Moment Correlation Coefficients Between Abstract Ability and Abstract Preference Scores for Six Groups of College Freshmen.

Group	n	r	Level of Significance
Science	200	.05	n.s.
Non-Science	266	-.13	n.s.
Chemistry	24	.41	.05
Biology	121	-.02	n.s.
Natural Science	54	.08	n.s.
Total	466	-.07	n.s.

TABLE 3 — A Simple Analysis of Variance of Abstract Ability Scores for Five Different Grade Levels.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between Groups	4	313.67	78.5	14.51 *
Within Groups	288	1557.51	5.41	
Total	292	1871.18		

$^{*}p < .01$

TABLE 4 — A Simple Analysis of Variance of Abstract Preference Scores For Five Different Grade Levels.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between Groups	4	15.22	3.80	1.15
Within Groups	288	1004.78	3.49	
Total	292	1020.00		

TABLE 5 — Product-Moment Correlation Coefficients Between Abstract Ability and Abstract Preference Scores for Five Different Grade Levels.

Grade Level	n	r	Level of Significance
8th	63	-.00	n.s.
9th	37	.01	n.s.
12th	102	-.26	.01
College Freshmen	95	.20	.10
College Seniors	27	.01	n.s.

TABLE 6 — Product-Moment Correlation Coefficients Between Abstract Ability and Abstract Preference Scores for Five Different Sub-groups of 8th Grade Science Students.

Sub-Group	n	r	Level of Significance
Males	29	-.21	n.s.
Females	34	.17	n.s.
High Abstract	3	.00	n.s.
Transitional	22	-.15	n.s.
Low Abstract	38	.26	n.s.

TABLE 7 — Product-Moment Correlation Coefficients Between Abstract Ability and Abstract Preference Scores for Five Different Sub-Groups of College Freshmen.

Sub-Group	n	r	Level of Significance
Males	27	.39	.05
Females	68	.13	n.s.
High Abstract	61	.30	.02
Transitional	28	-.11	n.s.
Low Abstract	6	.82	.05

It is interesting to note one exception to this lack of correlation, and that occurs for the chemistry majors.

When examining the abstract ability and the abstract preferences for science students ~~in five different~~ grade levels (8th, 9th, 12th, college freshmen, and college seniors) it was found that the abstract preferences do not significantly differ from grade to grade; however, abstract ability, as one would expect, does significantly increase as grade level increases (Tables 3 and 4).

Product-moment correlation coefficients were calculated between abstract ability and abstract preferences for each grade level, and the results indicated significant correlations at two grade levels. (Table 5). Subgroups (males, females, high abstract ability students, low abstract ability students, and transitional students) for grade eight and college freshmen were examined and correlations between abstract ability and abstract preference for each subgroup were calculated. From Table 6 it may be seen that in the 8th grade group, no significant correlation coefficients were found. However, from Table 7 one may see the significant correlations for the subgroups of male, high abstract ability, and low abstract ability.

SIGNIFICANCE AND DISCUSSION

As mentioned earlier, the assumption has been made by various science educators that the level of reasoning used by students when solving problems is substantially below the student's capacity. While recognizing other possibilities, one possible interpretation of this assumption is that students are functioning at a concrete level of thought, even though they have previously demonstrated the ability to function at the formal level of thought as defined by Inhelder[4] and Piaget.[5] Although more refined research is needed, this study has provided evidence that the possession of logical operations does not insure, or even suggest, the cognitive level of development at which a student will choose to operate.

Abstract ability for students in grades 8, 9, 12, 13 and 16 were compared, and the results indicated that hypothesis number three should be rejected. Students in these grade levels are at different levels of mental development. This was to be expected from both a Piagetian point of view as well as the logical point of view which takes into account the "dropping out" of lower ability students--especially at the 9th grade and college freshman levels. What was not so expected was the lack of evidence to reject hypothesis number 4; however, there was clearly no significant difference in the abstract preference scores among students of the five different grade levels. In short, most students, regardless of their abstract ability, would prefer to use much the same methods of solving a problem. It is realized that this finding may also be related to the nature of the items on the preference survey, and this is currently under investigation.

One must remember that the evidence does not indicate that 8th grade students would actually solve the problems in the same way as the college seniors, but rather, they tend to select the same methods which they would prefer to use in attacking a problem solving task. It is left for further research studies to determine, if after making an initial selection of problem solving methods, the student will actually use that method in solving the problem. Studies now being planned will investigate this question as well as the student's success achieved by various combinations of selection and use of problem solving methods.

The lack of correlation between abstract ability scores and abstract preference scores suggests that the student's preferred level of reasoning may be below his capacity for reasoning. When this situation occurs, students may be labeled as working below their capacity; however, it may well be that in certain instances a student in the formal stage of operations will be working at his capacity if he realizes that a concrete approach to a problem is the most efficient.

The situation changes when one finds a student in the concrete stage of operation who indicates a preference which would, in most likelihood, require logical operations which he does not yet possess. Regardless of which situation one considers, there are students selecting problem solving methods which do not correspond to their cognitive level of development.

When examining a total grade level, one may see that the low ability students are not any more likely to select a concrete method of problem solving than are the high ability students. This was also the case for subgroups within the 8th grade; however, because some of the subgroups within the college freshman level indicated moderate correlations, it is possible that as age increases, the relationship between abstract ability and abstract preferences becomes more pronounced.

A few words of caution are in order. First, it should be realized that the formal, concrete and transitional groups of students were identified by the use of an abstract reasoning test, the Shipley Test of Abstract Reasoning. By administering five traditional Piagetian-type tests to students and then administering the Shipley Test of Abstract Reasoning to the same group of students, it has been demonstrated that the Shipley Test does separate students into groups that at least approximate the formal, transitional, and concrete operational stages of development as defined by Piaget.[3] Therefore, the general terms of "abstract ability" and "cognitive level" are used almost interchangeably in this paper.

The abstract preference survey requires the students to make a forced choice between two responses. It may be that the instrument is functioning as a true/false test with all the limitations of such a test; however, approximately one third of the students are achieving extreme scores which are unlikely to be due to chance. Nevertheless, a revised version of the preference survey is currently being planned in which three choices will be available for each item.

Because a written problem solving task is itself an abstraction, the possibility exists that some of the student responses were influenced by their inability to properly understand the situation. This is being investigated in current studies.

In summary, it may be stated that the findings of this study support the assumption that a student's level of reasoning is often below his capacity; however, it is also true that many students actually prefer to function, or at least attempt to function, above their ability level. Further, it appears as though a student's preference and not his ability is the determining factor as to what method he will select to solve a problem. Teaching/learning models, as well as curriculum development efforts should take this into account. By realizing the role of an individual's style of preference in problem solving, educators can then concentrate on the acquisition of logical structures needed to implement the preference indicated by the student.

APPENDIX A

The Shipley Test of Abstract Reasoning

Complete the following. Each dash (__) calls for either a number or a letter to be filled in. Every line is a separate item. Take the items in order, but don't spend too much time on any one.

start here

(1) 1 2 3 4 5 __

(2) white black short long down __ __

(3) AB BC CD D __

(4) Z Y X W V U __

(5) 12321 23432 34543 456 __ __

(6) NE/SW SE/NW E/W N/__

(7) escape scape cape __ __ __

(8) oh ho rat tar mood __ __ __ __

(9) A Z B Y C X D __

(10) tot tot bard drab 537 __ __ __

(11) mist is wasp as pint in tone __ __

(12) 57326 73265 32657 26573 __ __ __ __ __

(13) knit in spud up both to stay __ __

(14) Scotland landscape scapegoat __ __ __ __ee

(15) surgeon 1234567 snore 17635 rogue __ __ __ __ __

(16) tam tan rib rid rat raw hip __ __ __

(17) tar pitch throw saloon bar rod fee tip end plank __ __ __ __ __ meals

(18) 3124 82 73 154 46 13 __

(19) lag leg pen pin big bog rob __ __ __

(20) two w four r one o three __

APPENDIX B

Abstract Preference Survey

This is NOT a test, but rather a preference survey. There are no right or wrong answers--only preferences. It consists of 18 problems each of which may be solved by more than one method. (Assume all methods could, if properly used, result in a correct solution.) As you read the items, select the method which YOU would prefer to use in arriving at the solution. You do not need to actually solve the problem at this time--just indicate which method you would prefer to use if someone asked you to solve the problem.

1. You are given three pieces of metal and are asked to identify them as to composition. Which would you more likely do first?
   A. Consult references such as handbooks, textbooks, and read about the theory and properties of metals.
   B. Test the metals with acids, bases, and other liquids in the laboratory to determine their properties.
2. You have just found an interesting fossil but don't know what it is. Which of the following methods would you use to identify the fossil?
   A. Study the fossil through written descriptions.
   B. Compare it to pictures which you have of various named fossils.
3. If you wanted to understand how a certain piece of equipment operated, would you
   A. Read the instructions as you examined and used the equipment.
   B. Read the instructions thoroughly prior to examining or using the equipment.
4. When driving in an area which is new to you, which of the following do you prefer to do?
   A. Decide upon the proper direction by "instinct" and/or reason.
   B. Decide upon the proper direction by using a map.
5. Read the following sentence: "I am very glad I do not like onions, for if I liked them, I would always be eating them, and I hate eating unpleasant things." Which of the following comments would you prefer to make concerning that sentence?
   A. Onions are unpleasant for some people to eat.
   B. There is a contradiction between "if I liked them" and "onions are unpleasant."
6. You want to learn how the parts of an electric motor fit together. In addition, you want to learn this as quickly as possible. Which of the following would you choose?
   A. Look at diagrams and read how the parts fit together.
   B. Take an actual electric motor apart and see how the parts fit.
7. On your last birthday you were given a small wooden puzzle. It has about 12 pieces and when properly assembled, it forms a solid cube. You are anxious to assemble this as easily as possible. Would you best like to
   A. Follow a diagram of how to put the pieces together.
   B. Follow the verbal instructions of a friend.

8. You are given a dryeell battery, two light bulbs, some wires, and a switch. You are asked to hook up the materials in such a way as to make both lights burn at the same time. What would you more likely do first?

   A. Study about electric circuits, sketches, diagrams, and then draw some yourself.
   B. Take the given materials and actually manipulate them in order to get the system to work.

9. You have been 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 type of the individual 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.

10. A 2 gram weight is placed exactly 6 centimeters 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 this question, which of the following methods would you choose?

   A. A mathematical approach using formulas.
   B. Actual manipulation of the weights.

11. You have decided to play the role of a cook and wish to try making something you have never made before. Which of the following would you prefer to use as a source of instruction?

   A. Learn how to do it by watching a famous cook on T.V.
   B. Learn by reading one of the famous T.V. cook's book.

12. Given the same situation as above:

   A. Learn by having a neighbor explain it to you.
   B. Learn by watching a famous cook on T.V.

13. You have been given 2 chemicals in liquid form and asked what happens if they are mixed together. How would you prefer to find out?

   A. Using chemical principles, a probable solution could be deduced.
   B. Under controlled conditions the two chemicals would be mixed together and observations would be made.

14. You just bought a new game which is designed to illustrate the basic principles of genetics. How would you prefer to learn to play this game?

   A. Begin immediately and read the rules as you play.
   B. Read the rules until you understand how to play and then play.

15. You are about to build a picnic table for you own use in your backyard. Which of the following methods would you prefer to use in the building of the table?

   A. Follow a set of plans (either your own or a set you purchased).
   B. Build the table "from you head" as you proceed.

16. You see a glass three-quarters full of water. When a stone is placed into the water, you notice the water level goes up. Which of the following would you prefer as a reason for your observation?

    A. The water will rise because the stone takes up space at the bottom.
    B. The stone is heavy; it will make the water rise.

17. If you were to visit a friend in another city for the first time, which of the following would you prefer to help you visualize the location of your friend's home?

    A. A little map sketched out for you on a peice of paper.
    B. A verbal set of instructions given to you.

18. You have been given a square object of unknown composition. Its weight and size are known. You wonder if it will float if placed in various liquids such as alcohol, oil, water, and gasoline. How would you prefer to determine if this object would float in each liquid?

    A. By experimentation under controlled conditions, you would observe the results.
    B. Calculate the objects density and compare this to the density of the various liquids. Formulas which you needed would be provided.

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