DOCUMENT RESUME

ED 255 358 SE 045 427

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TITLE Measured Formal Thought and That Required to Understand Formal Concepts in Secondary School Biology.
PUB DATE 85
NOTE 11p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (58th, French Lick Springs, IN, April 15-18, 1985).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Abstract Reasoning; *Biology; Cognitive Processes; *Comprehension; High Schools; Logical Thinking; Science Education; *Scientific Concepts; *Secondary School Science
IDENTIFIERS *Formal Operations; Science Education Research

ABSTRACT

Students (N=22) enrolled in secondary school biology were evaluated for their abilities to use: combinatorial logic; correlational reasoning; separation and control of variables; exclusion of irrelevant variables; proportional reasoning; and probabilistic reasoning. Each student responded individually to six Piagetian tasks designed to measure their levels of function on the six variables. Students were then asked two questions. The first question (which tested understanding of the concept "Plant growth is not affected by chemicals.") required correlational reasoning, combinatorial logic, separation and control of variables, and exclusion reasoning. Although the 22 students could have shown formal thought 88 times, only 24 such instances were found. The second question (which tested understanding of the concept "Heredity and environment interact in the expression of traits.") required combinatorial, probabilistic reasoning, proportional reasoning, and separation of variables. Again, although it was possible to demonstrate formal thought 88 times, only 25 instances were found. These and other findings indicate that using specific formal operations with which students demonstrate they can function, is not a good predictor of success on a question whose satisfactory response requires those specific formal operation. Thus, the exact formal operations necessary to understand a formal concept need not be isolated. (Author/JN)

ED255358



# Measured Formal Thought and That Required to Understand Formal Concepts in Secondary School Biology

by

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SE 045 427

MEASURED FORMAL THOUGHT AND THAT REQUIRED TO UNDERSTAND FORMAL CONCEPTS IN SECONDARY SCHOOL BIOLOGY

Abstract

In The Growth of Logical Thinking*, Piaget and Inhelder describe the operations and schemata which are postulated as being the characteristics of formal operational thought. Those formal thought characteristics, therefore, are used in solving problems and responding to questions which require formal thought. The hypothesis can be made, therefore, that persons who possess certain characteristics of formal thought will do better on tasks judged as requiring those characteristics than those persons who do not possess them.

Using the individual interview technique, 22 students enrolled in secondary school biology were evaluated for their abilities to use combinatorial logic, correlation reasoning, separation and control of variables, exclusion of irrelevant variables, proportional reasoning, and probabilistic reasoning. The performance of each student in the interviews was treated as a measure of the degree to which that student could function with those six formal-thought characteristics.

The research began by preparing several biology questions which required one or more of the foregoing six formal operations in responding satisfactorily. The questions were content validated and the operations required were also judged. Both validations were done by panels. Only two questions survived both validations.

Question One was judged to require correlation reasoning, combinatorial logic, separation of variables and exclusion reasoning. The 22 students, therefore, could have shown formal thought 88 times; only 24 such instances were found. Question Two was judged to require combinatorial, probabilistic and proportional reasoning and the separation of variables. Again it was possible to demonstrate formal thought on Question Two 88 times; formal thought was demonstrated 25 times. At no time were the specific formal operations indicated by the panel as being needed to solve Question One used by the 24 students who demonstrated on the tasks they could use those specific operations. Only seven times -- of 25 possible -- on Question Two were the specific formal operations used that were cited by the panel as being necessary to produce a satisfactory response to that question. In a very few cases formal thought was demonstrated on the questions but had not been demonstrated during the interview. Those few deviations will be treated in the presentation.

*Barbel Inhelder and Jean Piaget, The Growth of Logical Thinking, Basic Books, Inc., New York, 1958

In view of the data cited earlier, the conclusion was drawn that using specific formal operations with which students demonstrate they can function, is not a good predictor of success on a question whose satisfactory response requires those specific formal operations. The explanation for that conclusion, we believe, is found in the fact that, with one exception, success on the interview tasks are highly correlated with each other. That piece of empirical data points to the unity of formal thought.

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Purpose of the Study.

The research to be reported was done to test the following hypothesis: If specific formal operations are required to understand certain biological concepts, then those high school students demonstrating the abilities to use those specific formal operations should be successful in developing understandings of biological concepts requiring the use of those specific formal operations.

Theoretical Basis for the Study.

According to Inhelder and Piaget (1958), formal thought structures have many specific characteristics which enable formal operational thinkers to separate and control variables, use exclusion of irrelevant variables and combinatorial reasoning and many other reasoning abilities. Presumably those operations are available to formal thinkers to use to solve problems which require formal operational thought. Suppose that some formal biology concepts were analyzed to ascertain the specific formal operations required to understand those concepts and the thought of biology students was analyzed to determine which formal operations they are capable of using. Comparing the types of thought the concepts required to the types of thought the students possess might be useful in determining why students demonstrate misunderstandings of formal concepts as research has shown they do (Marek, in press; Renner, et. al., 1981; Shepherd and Renner, 1982).

Procedures of the Study.

The student sample which supplied the data included here consisted of 22 tenth-grade biology students from a large suburban high school. The students were in the honors class in biology in which the BSCS Blue Version was used.

Each student responded individually to six Inhelder-Piaget tasks (1958) designed to measure the students' levels of functioning on specific formal operations. Those tasks are: Combinational reasoning, correlation reasoning, exclusion of irrelevant variables, probabilistic reasoning, proportional reasoning and the separation and control of variables. The IIA, IIB, IIIA, IIIB designations of Piaget were used in scoring the performance of each interviewee on each task.

In order to compare student use of the formal operations on the tasks with the use of those same formal operations in answering questions, answering the questions correctly had to require the use of formal operational thought. Using the criteria for a formal concept established earlier (Lawson and Renner, 1975), several questions were prepared and submitted to a panel of biology teachers and biologists for content validation. In addition, the formal operations required in answering the questions were also judged by an expert panel. Only two questions survived both validations. The questions were giv to a group of high sch ol students in a non-participating school to gain an idea of the types of answ could be expected and to test the questions' language and reading levels.

Question One tested understanding of the concept: "Plant growth is not affected by chemicals." Responding to Question One correctly was judged by the validating panel to require the specific formal operations of correlation, combinatorial logic, separation of variables and exclusion of irrelevant variables. Question Two tested understanding of the concept: "Heredity and environment interact in the expression of traits." That question was judged to require the use of the specific formal operations of probability, combinatorial logic, separation of variables and proportional reasoning in formulating a satisfactory response. The performance of every student on each operation required to respond satisfactorily to each question was compared with the performance of the individual students on each interview task.

Results.

If all twenty-two students in the sample were formal, formal operational thought would have been demonstrated 88 times on each question--22 students and four operations per question. Not all 22 students, however, were classed IIIA or IIIB. In fact, among those formal operations needed to satisfactorily respond to Question One, IIIA and IIIB thought were demonstrated only 24 times (27.3 percent). Among the formal operations needed to satisfactorily respond to Question Two, IIIA and IIIB thought were demonstrated through the interviews 25 times (28.4 percent).

On Question One 24 agreements between the formal operations demonstrated on the tasks and those formal operations needed to satisfactorily respond to the questions could have been found. No agreements were found. A total of 25 such formal thought agreements could have been found on Question Two; seven--28 percent--were isolated. In sum, agreement between the performances on tasks and questions could have occurred 49 times and that agreement occurred only seven times--14.3 percent.

Earlier the point was made that if all the students were found operational, formal thought could have been demonstrated 88 times per question; formal thought was demonstrated 24 times on Question One and 25 times on Question Two. The converse of the foregoing summary statement is that formal operational thought was not demonstrated 64 times on Question One and 65 times on Question Two.

Four times on Question One and nine times on Question Two a particular formal operation was used by a student in satisfactorily responding to a question. That same student, however, had not demonstrated competency with that particular formal operation during his/her task interview. One person contributed three of these incidents on Question One and three on Question Two. No other person displayed that event more than twice. Our judgment is that that person should be dropped from further consideration because of such conflicting data. When that student is dropped from further consideration, the discrepant event just described occurred only once of 64 possibilities (1.6 percent) on Question One and 6 of 65 possibilities (9.4 percent) on Question Two. Obviously, the event is not important on Question One. The class had just completed a unit on genetics and perhaps the concrete operational students had retained enough memorized information to give the appearance of using the proper formal operation.

The data presented here do not support the hypothesis stated earlier. Even if students demonstrate the ability to use specific formal operations on the interview tasks, there is not assurance that those same formal operations will be used in responding to a question which is judged to require their use in order to produce a satisfactory response. Earlier research (Lawson and Renner, 1975; Cantu and Herron, 1978) has demonstrated that formal thought is necessary to learn formal concepts, which the concepts in this research were judged to be. To conclude, therefore, that specific formal operations are not necessary, seems contradictory. There is, we believe, an explanation for that occurrence which points to the unity of formal thought.

Table 1 shows the correlations which exist among student performances on the formal operational task taken two at a time. With one exception--proportional reasoning versus combinatorial reasoning--all those correlations are positive and many are reasonably high. Those data suggest that looking at the individual formal operations is not necessary; all that is necessary is to know that a person is formal operational to predict what types of concepts he/she will be successful with.

## Implications for Science Teaching.

The results of this research do a great deal to simplify the work of the science teacher. The exact formal operations necessary to understand a formal concept need not be isolated. The criteria established earlier (Lawson and Renner, 1975) can be used to identify formal concepts and those concepts can be then used with students who have been evaluated as reasoning at the formal level. Further-more, fewer tasks can be used to assess the operational levels of students. That finding is consistent with the findings of Shayer and Adey (1981).

Table 1. Correlations Among Student Performances on the Formal-Operational Task Interviews

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | 1 | | | | | |
| B | 0.43 | 1 | | | | |
| C | 0.23 | 0.42 | 1 | | | |
| D | 0.35 | 0.41 | 0.40 | 1 | | |
| E | 0.36 | 0.68 | 0 | 0.51 | 1 | |
| F | 0.50 | 0.5[illegible] | 0.16 | 0.37 | 0.64 | 1 |

A Probability
B Correlation
C Combinatorial REasoning
D Separation of Variables
E Proportion
F Exclusion of Irrelevant Variables

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