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ABSTRACT

Presented is a study in which the authors developed a valid and reliable test of integrated science process skills for students in secondary schools. The field trials are described and the reliability is given as .89 across ability levels, socioeconomic levels, gender, and race. Recommended uses of the test for teachers, researchers, and evaluators are included. (SA)

A TEST OF THE INTEGRATED SCIENCE PROCESS SKILLS FOR SECONDARY SCIENCE STUDENTS

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Many science curriculum guides and textbooks have as important outcomes the acquisition of the integrated science process skills. Students using these materials are expected to develop such skills as stating hypotheses, operationally defining variables, designing investigations, and interpreting data in addition to mastering the content of the courses. But if these integrated skills are emphasized by instructors, then they need a means to assess the acquisition of the skills. The purpose of this project was to develop a valid and reliable test of the integrated science process skills that could be used by teachers, evaluators, and researchers with secondary science students.

Background Literature

During the 1960's and 1970's the move to incorporate more inquiry and investigations in science classes was accompanied by efforts to measure these outcomes. Walbesser (1965) and others associated with the Science-A Process Approach curriculum developed a test of the basic and integrated process skills especially intended for elementary children using the curriculum. McLeod, Berkheimer, Fyffe, and Robison (1975) developed the Group Test of Four Processes to measure the skills of controlling variables, interpreting data, formulating hypotheses, and operationally defining. This test was designed to measure these skills as defined by the Science-A Process Approach elementary school science curriculum. Ludeman (1975), building on the work of McLeod, et al. developed The Science Processes Test. Again, this test was aimed at the elementary grade levels. Riley (1972) developed the Test of Science Inquiry Skills (TSIS) for fifth grade students. The TSIS measures the skills of identifying and controlling variables, interpreting data, predicting, and inferring as defined by the Science Curriculum Improvement Study elementary science program.

In an attempt to separate a process skills test from a specific curriculum, Molitor and George (1976) designed a test to assess the inquiry skills of inference and verification. Their test was designed for grades four, five, and six. Tannenbaum (1968) developed a test for use in grades, seven, eight, and nine. This instrument, Test of Science Processes, assessed the skills of observing, comparing, classifying, quantifying, measuring, experimenting, inferring, and predicting.

In addition to tests for students, tests of the process skills have been developed for teachers. Burns (1972) developed a test to measure the acquisition of the integrated science process skills by undergraduate elementary education majors. A guide prepared to help teachers learn the process skills associated with Science-A Process Approach includes appraisal items for teachers (American Association for the Advancement of Science, 1967).

Of the science curriculum projects for secondary schools, only the Biological Sciences Curriculum Study has a test specifically designed to measure process skill competence. This instrument, Processes of Science Test, measures how competent students are in the processes of science. Although the test purports to be general rather than biological science specific, the test items show an exclusive use of biological concepts and examples.

The preceding references to test construction all come from the period of the sixties and seventies. But assessment of the process or problem-solving component of science learning can be traced back much further. Champagne and Klopfer (1977) review reports and descriptions of process-oriented problem solving that begin as early as 1916. In these early studies, attempts to measure knowledge of problem solving or the methods of science appear to combine tests of specific skills (e.g., arranging data in sequence) and of scientific practices (e.g., suspending judgment).

The search of available process skills tests showed the need for a test geared to secondary students and not associated with any particular science curriculum.

Procedures

The science process skills selected for testing are those associated with planning, conducting, and interpreting results from investigations. Usually referred to as the integrated science processes, they include formulating hypotheses, operationally defining, controlling and manipulating variables, planning investigations, and interpreting data (Livermore, 1964). Objectives (see Figure 1) for each selected process skill were written. These objectives collectively lead to the ultimate task or planning and conducting an investigation.

Insert Figure 1 About Here

A major consideration in developing a process skills test is that of test format. While one wants students to demonstrate the integrated skills, the problem of using hands-on procedures to assess skill acquisition by groups of students can be a burdensome task. Faced with five or more classes and thirty or so students per class, science teachers need a means of measuring process skill competency that can be administered efficiently and objectively. Therefore, a decision was made to utilize a paper and pencil group testing format.

Three multiple-choice test items (each with four alternatives) were written for each of the nine outcomes shown in Figure 1. Objective A had four parts so a total of 36 items were written. Content was chosen from a variety of science fields so that the items were not based on a detailed knowledge of any subject field.

The Test of Integrated Process Skills (TIPS) that resulted from the process described above was su'mitted to a panel of four science educators to establish the content validity of the test, the objectivity of the scoring key, and the clarity of the items. To determine content validity, the panel was given a copy of the test items and a list of the outcomes and asked to identify which test items corresponded to which outcomes. The panel also completed the test so the scoring key could be verified. Comments on item clarity along with the validity and objectivity data were used to make modifications in some items. For a total of 144 responses (4 raters X 36 items), the experts agreed with the test developers on the assignment of test items to objectives 95% of the time and agreed with the scoring of the test 97% of the time. This concurrence of raters was taken as evidence of content validity and objectivity of scoring.

Field Trial 1

The first field trial was conducted in a community of approximately 50,000. The racial composition of the schools is about 35% minority and 65% white. Busing brings in rural students, thus resulting in school populations of mixed rural and urban students. Although random selection of subjects was not possible, classes were selected that reflected all facets of the school population. Approximately 100 students each from grades seven, nine, and eleven in two schools were tested in the first trial. The purposes of the first trial were to establish time to complete the test, to determine clarity of test directions, and to establish difficulty and discrimination indices for the test items.

The test was administered to a sample of 308 students. The mean score was 18.75 and the standard deviation was 7.59. Reliability (Cronbach's α) based on the total sample was equal to .88. The mean item discrimination index was .39 and the average item difficulty index was 52%.

Test Revisions

An assessment of the test readability level (Heilman, 1972) showed it to be higher than desired (about 11th grade). Words such as experiment, variable, investigation, and manipulated are used frequently in the test and caused the readability to be high. Further, the correlation (point biserial) of item scores with total test scores showed that several items were not discriminating well between high and low scoring students. These two factors (readability level and item discrimination) led to revisions in about half of the test items. Sentences were shortened and items that seemed hard to read were clarified. Figure 1 provides examples of the test items included in the final version of the test.

Field Trial 2

The revised version of the test was administered in a large school system in a community of approximately 100,000 in an adjoining state. A sample of more than 700 students from grades seven, nine, and eleven was selected. The racial and rural/urban composition of this system is similar to that of the system used for the first field trial. Again classes were selected to provide representation across ability levels, socioeconomic levels, gender, and race.

Results

The revised version of the test was administered to a sample of 709 students. The mean of the second version of the test is 18.99 and the standard deviation is equal to 7.60. With no specific training in the integrated process skills, students scored on the average about mid-range on the 36-item test. This allows considerable room to record increases in achievement for students receiving instruction with an emphasis on process skills.

Reliability of the test (Cronbach's α) is equal to .89. The mean item discrimination index is .40 and the average item difficulty index is 53%. Each of these three test characteristics is within acceptable limits for reliable tests (Payne, 1974). An estimate of the readability index is 9.2. Although this value of readability level seems a bit high, it results from the necessary use of multiple syllable words associated with investigating. Table 1 gives descriptive data by grade level and overall for the final version of the test. Based on these results from the second field trial, no further changes in the test were considered necessary.

Insert Table 1 About Here

Figure 2 summarizes descriptive characteristics of the Test of Integrated Process Skills.

Insert Figure 2 About Here

Conclusions

It should be emphasized that the purpose of this project was not to make inferences about the level of process skill attainment of a specific group of students. The tryout students had not had specific or intensive instruction in process skills. The scores reflect process skill capabilities of students that result from a range of content-oriented science teaching practices. Instead, the intent of the project was to develop a measure of integrated process skill achievement referenced to a specific set of objectives. The Test of Integrated Process Skills (TIPS) appears to be a valid and reliable measure of process skill achievement for students in the seventh to twelfth grade range.

Use of the test* is recommended to teachers, researchers, and evaluators in ways such as the following:

1. Research studies in which the dependent variable is student acquisition of the science process skills.
2. Teaching skills research where the effectiveness of certain teaching practices is measured by process skill achievement.
3. Assessing process skill competency by classroom teachers where the process skills are an important outcome of science instruction.
4. Tests of the effectiveness of materials or modules designed to aid students in learning science process skills.
5. An alternative to a laboratory procedure as a way to assess process skill acquisition.

*Copies of the test for use in research and evaluation studies can be obtained from the authors.

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Objectives	Sample Test Item
A. Given a description of an investigation, identify the independent, dependent, and controlled variables and the hypothesis being tested.	Sarah wanted to find out if temperature has an effect on the growth of bread mold. She grew the mold in nine containers containing the same amount and type of nutrients. Three containers were kept at 0°C, three were kept at 90°C, and three were kept at room temperature (about 27°C). The containers were examined and the growth of the bread mold was recorded at the end of four days. The dependent or responding variable is: 1. growth of bread mold 2. amount of nutrients in each container 3. temperature of the containers 4. number of containers at each temperature
B. Given a description of an investigation, identify how the variables are operationally defined.	The superintendent is concerned about the accidents in schools. He makes the hypothesis that safety advertising will reduce school accidents. He decides to test the hypothesis in four middle schools. Each school will use a different number of safety posters to see if the number of accidents are reduced. Each school nurse will keep a record of students that come to the office because of an accident. How is safety advertising measured in this study? 1. number of accidents reported to the nurse 2. number of middle schools involved 3. number of safety posters in each school 4. number of accidents in the school
C. Given a problem with a dependent variable specified, identify variables which may affect it.	Sue wants to find out what might affect the length of bean seedlings. She places a bean wrapped in moist tissue paper in each of ten identical test tubes. She puts the other five tubes in a rack in a sunny window. She puts the other five tubes in a rack in a sunny window. She puts the other five tubes on a rack in a dark refrigerator. She measures the lengths of the bean seedlings in each group after one week. Which of the following variables might affect the length of the bean seedlings? 1. temperature and moisture 2. moisture and length of test tubes 3. light and temperature 4. light and amount of time
D. Given a problem with dependent variables specified and a list of possible independent variables, identify a testable hypothesis.	A student has been playing with a water rocket. He can change the amount of water in the rocket and the angle at which he releases the rocket. He can also change the weight of the rocket by adding sand in the nose cone. He wants to see what might affect the height to which the rocket will rise. Which of the following is a hypothesis he could test? 1. Rockets with warm water will rise higher than rockets with cold water. 2. Rockets with four tail fins will rise higher than rockets with two tail fins. 3. Rockets with pointed nose cones will rise higher than rockets with rounded nose cones. 4. Rockets with more water will rise higher than rockets with less water.
E. Given a verbally described variable, select a suitable operational definition for it.	The effect of exercise on pulse rate is studied by a science class. Students do different numbers of jumping jacks and then measure pulse rate. One group does jumping jacks for one minute. A second group does them for two minutes. A third group jumps for three minutes. A fourth group does not jump. How would you measure the pulse rate in this study? 1. by counting the number of jumping jacks for one minute 2. by counting the number of heart beats in one minute 3. by counting the number of jumping jacks done by each group 4. by counting the number of exercises for each group
F. Given a problem with a dependent variable specified, identify a testable hypothesis.	Some chickens lay an egg almost every day. Other chickens produce few eggs. A study is planned to examine factors that might affect the number of eggs produced by chickens. Which of the following is <u>NOT</u> a suitable hypothesis for the study? 1. More eggs are produced by chickens that receive more hours of light. 2. The more eggs produced by chickens the more weight they lose. 3. The larger the cage for chickens the more eggs they will produce. 4. The more protein there is in the feed the more eggs produced.

Figure 1. Objectives and sample test items for TIPS.

Objectives	Sample Test Item
G. Given a hypothesis, select a suitable design for an investigation to test it.	John wonders what affects the time it takes ice cubes to melt. He thinks that the size of the ice cubes, temperature of the room, and the shape of the ice cube are all factors that might affect the melting time. He finally decides to test the hypothesis that the shape of an ice cube affects the time it takes to melt. Which design should John select to test his hypothesis?

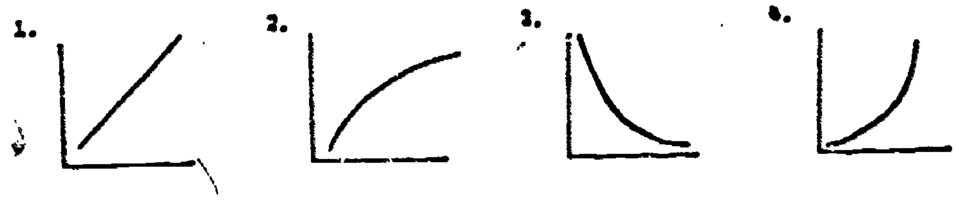
1. Use five ice cubes, each with a different shape and weight. Use five identical containers, all at the same temperature. Observe the melting time of the ice cubes.
2. Use five ice cubes, all having the same shape, but each having a different weight. Use five identical containers, all at the same temperature. Observe the melting time of the ice cubes.
3. Use five ice cubes, all having the same weight, but each having a different shape. Use five identical containers, all at the same temperature. Observe the melting time of the ice cubes.
4. Use five ice cubes, all having the same weight, but each having a different shape. Use five identical containers, each at a different temperature. Observe the melting time of the ice cubes.

H. Given a description of an investigation and obtained data, identify a graph that represents the data.

A science class was studying pressure and volume with balloons. They did an experiment in which they changed the pressure on a balloon and then measured its volume. The results are given in the table.

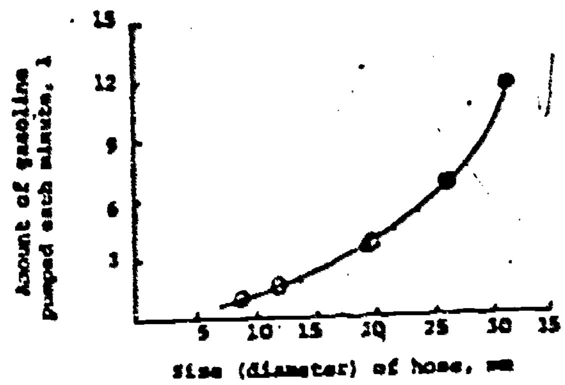
Pressure on balloon (N/cm^2)	Volume of balloon (ml)
0.35	980
0.70	400
1.05	320
1.40	220
1.72	180

Which of the graphs shows the data correctly?



I. Given a graph of data from an investigation, identify the relationship between the variables.

Hoses of 5 different sizes are used to pump gasoline from a tank. The same pump is used for each hose. The graph below shows the findings in the study.



Which statement describes the relationship between the variables?

1. The larger the diameter of the hose the more gasoline pumped each minute.
2. The more gasoline pumped each minute the more time is needed.
3. The smaller the diameter of the hose the more gasoline is pumped each minute.
4. The smaller the amount of gasoline pumped the larger the diameter of the hose.

Figure 1. Continued

Table 1

Descriptive Statistics for the Test of Integrated Process Skills (TIPS)

Grade	N	Mean	S.D.	Reliability
7	250	15.39	6.76	.84
9	255	19.83	6.46	.84
11	204	22.29	8.08	.91
OVERALL	709	18.99	7.60	.89

Process skills tested:	identifying variables operationally defining identifying testable hypotheses experimental design graphical analysis of data	
Number of items:	36	
Response format:	multiple-choice; four alternatives	
Recommended grade levels:	7-12	
Time to complete test: (average)	grade 7 -- 50 minutes grade 9 -- 35 minutes grade 11 -- 25 minutes	
Test readability:	9.2	
Discrimination index:	Average	Range
	.40	0 - .20 (2 items) .21 - .40 (12 items) .41 - .60 (22 items)
Difficulty index:	Average	Range
	53%	0 - 20 (2 items) 21 - 40 (6 items) 41 - 60 (15 items) 61 - 80 (13 items)
Reliability:	.89 (Cronbach's α)	

Figure 2. Characteristics of the Test of Integrated Process Skills