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Analysis of scientific thinking and attitudes changed by introductory physical science used as a high school physical science course.

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ANALYSIS OF SCIENTIFIC THINKING AND ATTITUDES CHANGED BY INTRODUCTORY PHYSICAL SCIENCE USED AS A HIGH SCHOOL PHYSICAL SCIENCE COURSE

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Chapter 1

INTRODUCTION

"Most new curricula in science are written largely by scientists for the purpose of encouraging, stimulating, and challenging the science prone student."[1] To illustrate courses written by National Science Foundation (NSF) authors include Physical Science Study Committee (PSSC), Chemical Bond Approach (CBA), Chemical Education Materials Study (CHEM study), Engineering Concepts Curriculum Project (ECCP), and Project Physics were designed for average and above average high school juniors and seniors. Project Physics, written nearly ten years later than PSSC physics, was aimed at a larger fraction of the population. However, the only science course developed for the purpose of helping the below average junior and senior high school students was Ideas and Investigations in Science (IIS), which was written later than all the above studies.

This reveals that the attention is now shifting from the academically talented toward a greater number of students with fewer capabilities. The necessity for science education to focus on a larger per cent of the population, people of

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[1]A. Miles Weaver III, "The Forgotten Majority: Science Curriculum", Science Education, LIV (January, 1970), 5.

average ability, has been amplifed through the supply of scientists meeting the demand. There is no longer the exigency for highly skilled scientists now that the government is reducing its research and science support.

Accordingly, there is now a definite need for more attention directed to average and below average science students. Science educators are faced with the problem of selecting a course for those students that will accomplish two tasks, (1) encompass sufficient cognitive, affective, and psychomotive science principles and, (2) endow the kinds of thinking skills, methods, and attitudes normally associated with science.

Making a proper selection which will take into account the many variables that exist in students is a difficult task. Furthermore, after a choice is selected, there exists a necessity for a thorough study of its weaknesses and strengths. This is also echoed by Welch in these following words.

> Unfortunately, there is a strong and persistent feeling that if a program is funded by the government and written by scientists, then teachers are relieved of adoption decisions. It is assumed by many that the program must be good and should be used by all. But this belief is highly questionable and should be challenged by teachers. Evaluation of the program is still required, and teachers should use the information to reach rational rather than emotional decisions.[2]

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[2]Wayne Welch, "Curricular Decision", The Science Teacher, LXVII, (November, 1968), 42.

The Problem

The secondary education system in the United States attempts to prepare students for all types of future vocations. Whatever preference of work chosen, science will be used by all. Future doctors and biologists will use science in a more sophisticated nature than others, yet people in all fields will find scientific thinking and methods beneficial.

High school chemistry and physics have become courses only for those academically talented students planning to enter a scientific profession. The reason for this is that since 1957, when man first put an object in outer space, there has been an emphasis on science for those working in occupations relating to the science field. However, people in other occupations will find it necessary to make decisions and labor at skilled tasks that require reasoning. These individuals will need to know general scientific methods to better accomplish their endeavors. Therefore, our secondary education system needs to supply instruction in scientific thinking for these people. One such course designed to help students think scientifically is Introductory Physical Science (IPS).

Statement of the Problem

The purpose of this project is to analyze IPS as a high school physical science course in two ways: (1) to determine if it produces measurable advances with non-science students in the kinds of thinking skills, methods, and attitudes normally associated with science. The Test on

Understanding Science (TOUS) is used as an inventory to evaluate the thinking skills, methods, and attitudes associated with science and (2) to determine the behavior/s that is changed by non-science high school students completing IPS.

Additional light will be shed on both problems by dividing the students into two ability groups: lower and upper.

Hypotheses

The hypotheses are divided into two general parts. They are hpotheses I and II. Number I involves the results of test scores, and Number II tests an item analysis. Numerous secondary hypotheses follow each general hypothesis. General hypothesis I reads:

I. There is no significant difference in pre- and post-test scientific thinking scores, as measured by the TOUS test by students completing IPS.

The analysis of test scores will be continued in the testing of each of the following secondary hypothesis.

A. There is no significant difference between pre- and post-test scientific thinking scores of the low group (students whose average ITED Natural Science Reading and Background scores were below the 50th percentile based on Iowa norms) or the upper group (whose average ITED Natural Science Reading and Background scores were above the 50th percentile).

B. There is no significant difference between pre- and post-test scores of "The Scientific Enterprise" portion of the TOUS test.

C. There is no significant difference between pre- and post-test scores on "The Scientific Enterprise" by the low or upper group.

D. There is no significant difference between pre- and post-test scores of "The Scientist" portion of the TOUS test.

E. There is no significant difference between pre- and post-test scores on "The Scientist" by the low or upper group.

F. There is no significant difference between pre- and post-test scores of "The Methods and Aims of Science" portion of the TOUS test.

G. There is no significant difference between pre- and post-test scores on "The Methods and Aims of Science" by the low or upper group.

H. There is no significant change in correlation coefficient between IQ and Scientific Thinking pre- and post-test scores.

I. There is no significant change in correlation coefficient between Reading of Natural Science and Scientific Thinking pre- and post-test scores.

J. There is no significant change in correlation coefficient between Background in Natural Science and Scientific Thinking pre- and post-test scores.

K. There is no significant change in correlation coefficient between quantitative thinking and Scientific Thinking pre- and post-test scores.

The second general hypothesis to be tested is in relation to the item analysis on the TOUS test.

II. There is no significant difference between the number of responses which changed from wrong to right and from right to wrong on the TOUS pre- and post-test scores of scientific thinking by non-science students enrolled in IPS.

Further analysis of the general hypothesis II will be aided by testing each secondary hypothesis below.

A. There is no significant difference between the number of responses which changed from wrong to right and from right to wrong on pre- and post-test scores of scientific thinking within the low group.

B. There is no significant difference between the number of responses which changed from wrong to right and from right to wrong on pre- and post-test scores of scientific thinkingiwithin the upper group.

Procedure and Population

The population of students chosen for the research study described were students at the Denison High School, Denison, Iowa, who enrolled for the course called physical science during the school year 1970-71. The course was open as an elective to all tenth, eleventh, and twelth grade students as a second, third, or fourth year of science in the high school.

Two years of science are required in grades nine through twelve, therefore the tenth grade students taking physical science were using it to fullfil their science requirement. Sophomores also have a choice of two tracks of biology to fullfil minumum education requirements. The eleventh and twelth grade students in physical science were ones not desiring the rigorous chemistry or physics courses, but desired another science course.

Fifty-nine students began physical science in the fall of 1970. There were fifty-two students who completed the course. The seven students who did not complete the course dropped the class because two lacked interest, one had taken IPS in junior high at another school, two moved away, and two dropped out of high school. Of those completing the course, ten were sophomores, twenty-three were juniors, and ninteen were seniors. The ten sophomores were starting their second year of high school science, forty-one eleventh and twelth graders were starting third year and one senior was in his fourth year of high school science.

To determine if these fifty-two physical science students scored better on post-test than pre-test scores on each section, the total TOUS test results was analyzed for a significant gain in each group; lower, upper, and entire. The t-test was employed and confidence limits set at ,05 level. The Null Hypothesis was used. Little confidence was placed on the results of Scale I, The Scientific Enterprise; Scale II, The Scientist; and Scale III, The Methods and Aims of Science of the TOUS test since their reliability is only .58, .52, and .58, respectively.

Correlation coefficients were figured among IQ, ITED Natural Science Reading, ITED Natural Science Background, ITED Quantitative Thinking, and TOUS pre- and post-test scores. Then it was determined if the changes in the correlation coefficients showed a significant gain from pre- to post-test with the effects of IQ, ITED Natural Science Reading, Natural Science Background, ITED Quantitative Thinking taken out.

An item analysis was completed by using a McNemar's chi squared formula to determine if the change toward or away from the right answer was significant. Then a proportion of students making each response was found for the questions with a significant change.

Definition of Terms

High School-Grades 9, 10, 11, and 12.

IPS-Introductory Physical Science. An inquiry type physical science course written for junior high students by a group of authors supported by the National Science Foundation and published by Prentice Hall.

ITED Test-Iowa Tests of Educational Development. An every student inventory of academic achievement written and distributed in Iowa by the Iowa Testing Program, University of Iowa, Iowa City, Iowa.

TOUS Test-Test on Understanding of Science written by Cooley and Klopfer copyright 1961, and published by the Educational Testing Service.

Low Group-The student group whose average ITED Reading and Background in Natural Science percentile is less than 50 based on Iowa norms.

Entire Group-All students completing physical science cource at Denison Community High School, Denison, Iowa, during the 1970-71 school year.

Non-Science Students-Students taking physical science instead of physics and chemistry.

Assumptions

Much confidence has been placed in the TOUS test by Cooley and Klopfer, copyright 1961, published by the Educational Testing Service. The experimenter assumed that the science behaviors measured by the TOUS test are those that the students not enrolled in physics or chemistry should improve. A reading level compatible to the group of high school physical science students is also assumed to be structured into Form W of the TOUS.

The date each test was given should not have affected the scores through mental attitude. The pre-test was given the first day of school and the post-test two weeks before the last day of school. The post-test was not given following a school sponsored activity.

Delimitations

All high school students were considered as a unit with no factor for grade level since physical science was open to all students who desired such a course.

The student's reading ability was considered equally as important as the student's background in natural science in assigning groups (lower and upper) since IPS was written on a grade level below that of any student enrolled.

No control group was used, consequently this research is limited to growth and behavior changes.

Chapter 2

REVIEW OF RELATED LITERATURE

Direction of Science Education Research

Research needs to have a defined, long range goal in mind which would enable all researchers to work toward one direction thus making for maximum science research efficiency. At the present time, science researchers are seeking the right course. This may slow down achievement of end results due to the fact that many researchers have individual goals but few collective ones. The diversity in directions has come about largely because society has asked for it. Society desires to have research more productive in solving social problems. Well-defined, long range goals such as those efforts which were directed toward putting a man on the moon is what is needed in science research. "Excessive efforts to make science more productive in terms of immediate social goals may actually make it far less productive in the long run,"[1] Abelson reports.

Science education is fortunate in that it is not plagued with the direction problem that science technology is faced with today. "Educators realize the value of general

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[1] Philip H. Abelson, "Science and Immediate Social Goals," Science, CLIXX (August, 1970), 721.

education science for non-scientists."[2] It is interesting to note that just eleven years ago science education did not have the common goal it has today. Flowers found prevelant disagreement among educators on the following topics: content for mental training vs content of specific value, and training of specialists vs education for liberal arts. Science education research is concentrating its efforts today in content for mental training and education for liberal arts.[3]

A more definitive objective of a high school science course is to communicate, "broad, integrated understanding of science which should directly contribute to scientific method and critical thinking."[4] For example, educators are attempting to help children learn to analyze situations in a systematic fashion agreeable to scientists. It is impossible for an individual to learn enough specific values to help him make all decisions in life; therefore, scientific method and critical thinking are phenomana that will always be useful in resolving life's perplexities. Ruchlis wrote of the same concept on a professional basis as he referred to a man with a Ph.D. degree in physics who turned from

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[2]Norman A. Flannigan, "A Study of High School Science Courses in Grades 9-12 Designed for General Education," Dissertation Abstracts, XV (January-June, 1953), 600.

[3]John Flowers, Jr. "A Study of Selected Viewpoints Pertaining to Science Education," Dissertation Abstracts, XXI (January-March, 1961), 2158-9.

[4]Flannigan, loc. cit.

physics to economics, taking a commendable infusion of scientific comprehension into another area.[5] The author amplified the idea that a scientifically trained person has techniques that assist his thinking and the eventual solution of many diverse problems.

Science education is focused toward developing methods of helping individuals learn how to analyze problems in a scientific fashion. Klopfer pointed out that a science course for general education in 1991 will have its major emphasis on scientific inquiry.[6] The investigator contends that scientific inquiry is the practice of analyzing and solving problems. Research indicates that science education has its defined, long range goal; therefore, the stage is set for attempting teaching methods which might reach this goal with maximum efficiency.

Research Methods

Many conclusions of previous analyses of student growth have been established. One is the fact that if a number of students is divided into two achievement groups, upper and lower, the upper gains more than the lower. This was shown in the case of a college science course being taken by future elementary teachers. In this particular

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[5]Hy Ruchlis, "The Challenge of Anti-Science," Science Education, LV (April-June, 1971), 216.

[6]Leapold Klopfer, "Science Education in 1991," School Review, LLXXVII (September-December, 1969), 202.

science class the gain from the pre-test mean score to post-test mean score on the TOUS test was greater by the upper group than by the lower. In fact the post-test mean score of the lower group (42.45-fall, 39.00-winter) was very close to the pre-test mean score (47.70-fall, 45.92-winter) of the upper group.[7] The growth a student obtains in the understanding of science can be found by analyzing pre-test and post-test scores of a test designed for that purpose.

Another conclusion was noted by Stevenson in ninth grade science. Stevenson showed the ability of a student's co-workers affected his progress to the extent that it was significant at the .01 level. A student did better when placed in a group of higher ability. A student also achieved less when placed in a group of lower ability.[8]

In order to ferret the strong and weak points of a course, Klopfer and McCann suggested using a four-cell McNemar chi squared test of change on each test item. Form Jx of the TOUS test was given to freshmen at University High School, Chicago, Illinois, to access the accomplishments of the course entitled, Time, Space, and Matter. It was found that sixteen of the forty-five items had a significant

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[7] Roger Olstad, "The Effect of Science Teaching Methods on the Understanding of Science," Science Education, LIII (February, 1969), 10.

[8] Andrew Stevenson, "A Study of the Effect of Direct Teaching Versus Indirect Teaching Upon Ninth Grade Students in Science," Dissertation Abstracts, XXIX-A (May-June, 1969), 3783A.

change in response.[9] The analysis yielded the exact changes in behavior measured by Form Jx which occured between testings.

Klopfer and Cooley quoted the possibility of measuring affected methods of thinking in a study of ninth and tenth grade high school biology students. It could be shown here exactly which test item's responses were changed by the same course taught to ninthhand tenth grade students.[10] The significance of which grade it is better to teach biology is not an important issue compared to which behaviors are desirous to change. Each individual school system must make the choice of grade placement, but the individuals who decide can analyze the changes and select the grade level best fitting their science education philosophy.

The students' responses to questions are affected by many variables. One such function is that of the many aspects of "reading ability."

Reading Ability

Much of the United States school systems' success hinges on the students' ability to read. A poor or slow reader has problems in completing or doing lessons well,

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Leapold E. Klopfer and Donald C. McCann, "Evaluation in Unified Science Measuring the Effects of the Natural Science Course at the University of Chicago High School, Science Education, LIII (March, 1969), 159.

[10] William W. Cooley and Leopold E. Klopfer, "The Evaluation of Specific Educational Innovation," Journal of Research in Science Teaching, I (1963), 73.

taking tests, and at times contributing to class discussions. Therefore, many times the poor reader spends his time in studyhall looking at pictures in magazines or entertains himself by looking through periodicals. After an individual leaves or graduates from high school, about the only way he can continue to grow mentally is through reading. The purpose of the United States school system is to prepare young people for the future.

It was shown by Mallard that a relationship between reading ability and class ranking at the high school level existed at the .001 level of significance. The study originated when a group of students entered high school and was completed when the students graduated. It is interesting to note that the dependency of students' achievement on reading ability was true in the following situations: students in large and small high schools, schools of low and high per pupil costs, and by both sexes.[11] With the preceding evidence of reading ability's importance, it becomes necessary to pursue this topic further.

Many of the evaluation instruments in the classroom used today consists of written tests. This, of course, makes it essential for students to read the question, comprehend it, and then select the best response. The latter

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[11]Joseph R. Mallard, "The Relationship of Reading Ability to Rank in High School Class," Dissertation Abstracts, XXVIII, No. 9, 3372-A, reviewed by Edward Summers, "Summary of Doctoral Dissertations in Secondary School Reading," Journal of Reading, XII (May, 1969), 687.

step is supposedly all the instrument's scores are to measure. However, if there is a breakdown in either of the first two steps, an incorrect response will be registered and the score will be taken as indicating a shortcoming in the ability to select the correct response.

One study in Philadelphia, Pennsylvania, proved that a reading test in science can influence the scores of poor readers. Results of a fifth grade research pointed out that 86.3 per cent of slower readers scored better on a non-reading test while only 15 per cent of the better readers scored higher on a non-reading test.[12] One realizes not only did the poorer readers score better on the non-reading test, but also 15 per cent of the better readers improved their scores. The ability to read a science question on a test and obtain the meaning intended by the author requires a different type of reading skill than is generally taught. Carlson set up an experimental group of seventh and eighth grade students in which one group of seventh and eighth graders were taught how to read and the other group of students were not given the special instruction. The students in the reading instruction section of the seventh and eighth grades scored much higher in the speed of comprehending, ability to read and interpret literary and social studies

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[12]Leonard Pinkeistein, "The Development of a Reading Free Testing Procedure for the Evaluation of Knowledge and Understandings in Elementary School Science," Dissertation Abstracts, XXIIX (April-June, 1968), 3925-A.

materials, the ability to use source materials, but not to read science materials, than those in the control group.[13]

According to Drake, rewriting the science material to a lower grade level is not the solution to the science reading problems. He attempted to do that and found no significant improvement in the learner's comprehension, retention, or readind of the technical or non-technical content.[14]

One should realize that Drake was testing secondary school students. He rewrote the science material from the tenth grade reading level down to a fifth grade reading level based on the Dale-Chall formula. His research appears to relay the message that there is no improvement in the learner's reading speed, comprehension, and retention, by having material written grade levels below that of the student's ability.

Finkelstein in his study of fifth graders in Philadelphia found that a test must be written on or below the reading level of the students. If this is not followed, a severe handicap will evolve, and the test scores will be significantly lower.

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[13]Eleanor G. Carlson, "An Investigation of the Effect of Developmental Reading Instruction in Seventh and Eighth Grade," Dissertation Abstracts, XXVII, No. 9, 490-A, reviewed by Summers, loc. cit., p. 651.

[14]Lawrence Drake, "The Effectiveness of a Selected Readability Formula in Prediction of Student Success with Technical and Non-Technical Reading Materials," Dissertation Abstracts, XXVII, No. 9, 2937-A, reviewed by Summers, Ibid., p. 652.

Pinkeistein's and Drake's studies indicate that science materials must be written equal to or below the reading level of the students involved, or the students will not acquire the full meaning of the material. Many science educators have not heeded this belief.

For example, Powell found that chemistry texts generally had a reading level of 13-15 as determined by the Dale-Chall formula. The median reading level of 342 high school chemistry students tested was 12.4 as determined by the California Reading Test.[15] The largest group of students were reading at a level below that of most of the text books. Chemistry is difficult to understand without compounding the difficulty with a high reading level.

It is hoped that similar problems do not exist in other areas. If so, science educators need to take positive steps to correct the problem of text book reading level being above that of the student.

Another factor which affects students success in learning science is his index of relative speed with which he characteristically acquires new knowledge called his intelligence quotient, IQ.[16]

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[15]Merrill M. Powell, "An Analysis of Reading Level and Content of the Alabama State-Adopted High School Chemistry Texts for the Year 1965-66," Dissertation Abstracts, XXVII, No. 5, 1205-A, reviewed by Summers, Ibid., p. 688

[16]Myron A. Whitman, "Discrimination Learning as a Function of MA, IQ, and Institutionalization," Training School Bulletin, LXVII (August, 1970), 123.

Intelligence

The intelligence quotient is a quotient arrived at by dividing the mental age as established by a specified measuring instrument by the chronological age. Mental age is a difficult measure to obtain. Many authors have written instruments with which to assess a score, but each has been critized many times as to the method, content, and implications. However, intelligence is a valuable measure in education as the correlation coefficient between mental ability and accomplishments in science is significant at a very conservative level.[17]

Karnel describes intelligence tests in this way: These tests are much like the objective school examination. They are paper-and-pencil tests and usually consist of 75 to 125 multiple-choice items. The student reads the problem to himself and does one question after another within a fixed time limit.[18]

Once again a student who has problems reading would not receive an accurate score since most intelligence tests require reading. There are individualized non-reading intelligence tests, but these are not common because of the skill and time required by the tester. Whitman said that

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[17] Warren D. Shepler, "A Study of Scholastic Achievement in Secondary School Science in Relation to Pupil Relatives Preference for this Subject," Dissertation Abstracts, XVI (January-March, 1957), 1376.

[18] Louis J. Karmel, Testing in Our Schools (New York: Macmillian Co., 1966), p. 10.

intelligence is the relative speed an individual characteristically acquires new knowledge.[19] However, Johnson found IQ to correlate better with science reading ability than science background, r=.77 and .65 respectfully.[20]

Aside from the reading effect, intelligence as defined by Whitman is closely related to the area in science known as concepts.

There are several methods of facilitating the learning of concepts. One of these is an incubation period following intensive study. Another is the knowledge of the structure and vocabulary of one's native language.[21]

Concepts are usually formed only after a long and gradual process of learning to make fine discriminations between examples and non-examples of the concepts.[22]

Myers says that the ability to learn a particular concept is an interaction of broad experience and intelligence. He goes on to say that the method in which one learns a concept may determine its use in situations.[23]

Another ability quite highly related to intelligence is problem-solving. The exact cause of this relationship

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[19] Whitman, loc. cit.

[20] Jennings O. Johnson, "Science Achievement Charcteristics," Science Education, LIII (October, 1969), 310.

[21] Marshall E. Myer, "Some Implications of Empirical Studies on Higher Thought Processes for Science Education," Dissertation Abstracts, XXIV (July-September, 1962), 888.

[22] Ibid.

[23] Ibid.

is difficult to establish and in some situations impossible to identify and classify the types of stratedgy involved. Simple operant and classical conditioning research are the bases of one approach to human problem-solving while another treats it as particularly complex and highly developed kind of learning.[24] Recent studies have become more formalized, less naturalistic, to a certain extent, narrower in scope, and more quantitative and rigorous in an attempt to learn how human beings learn the art of problem solving.[25]

The fact that problem solving ability and the ability to establish concepts are influences on intelligence but yet they are not completely understood, brings to light why there is so much controversy over intelligence tests and IQ scores. It is often difficult to understand why so much emphasis is placed on an area which is controversial, has little proven research, and is still vaguely explained and understood.

Conclusion

The research indicates that inquiry is a profitable long range goal for science education. It is also evident that there are influences which affectt how well or even whether or not a student achieves competency in what are considered valuable scientific behaviors. Even though some

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[24] H. J. Butcher, Human Intelligence, Its Nature and Assessment, (London: Methuen, 1970), p. 77.

[25] Ibid.

of these influences are not clearly understood the stage is set for studies determining how particular applications of inquiry oriented instructional materials can either control or take advantage of these influences. Science researchers must bear in mind that these variables have to be utilized in such a way as to achieve greater efficiency in student attainment of necessary scientific behaviors.

Chapter 3

PROCEDURE AND STATISTICAL ANALYSIS

The analysis of scientific thinking and attitudes changed by Introductory Physical Science used as a high school physical science course will be accomplished in two general parts with secondary methods aiding the development of each part.

The first general part is to determine whether or not students' scores of scientific thinking changed significantly between the pre-test and post-test. The "Test on Understanding of Science," Form W, by Cooley and Klopfer, copyright 1961, published by Educational Testing Service was the inventory used to measure scientific thinking. The same form (W) was given as a pre-test and post-test with nearly nine months, one school year, between testing periods. During that time, all tenth, eleventh and twelfth grade students in the study, were studying the materials contained in "Introductory Physical Science," (IPS) copyright 1967, published by Prentice-Hall, as prescribed by the authors of IPS. Texts, problems, labs, quizzes, and tests (written and laboratory) were purchased from the author's recognized supplier and used as nearly as possible as the "Teacher's Guide for Introductory Physical Science" suggested. The instructor, Mr. Paul Wentworth, had received two semesters of graduate academic inservice training on philosophies, methods, and techniques of IPS under the direction of Dr. Dale Bunsen, at the University of Nebraska at Omaha, in the preceding year.

The second part of the analysis is to determine which behaviors, as stated in each item of the TOUS test, is changed by the students studying IPS. The tests, course, and students are those described in the preceding paragraph.

Part I

Many tests have been prepared to measure student achievement in facts and principles of science, but this research project is designed to measure intangible teaching and learning aspects of science. The intangible aspects of science are described by the TOUS test authors in the following matter:

> These intangibles include an understanding of the nature of scientific inquiry, of science as an institution, and of scientists as people.[1]

There are three individual scales of the TOUS test, measuring understanding in each of the following areas; (I) "The Scientific Enterprise," (II) "The Scientist," and (III) "Methods and Aims of Science." The total score is the sum of each individual scale score thus yielding a composite score weighted in proportion to relative importance as

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[1] W.W. Cooley and L.E. Klopfer, Test on Understanding Science, Form W Manual for Administering, Scoring, and Interpreting Scores (Princeton: Educational Testing Service), 1961, p. 1.

determined by the test's authors. Reliability of the entire test is quite high-.76, producing a standard error of measurement of 3.49.[2] This means that the likelihood of the observed total score deviating from an individual's true score by more than 3.45 points (plus or minus) is about two to onc.[3]

Measuring student growth in understanding of science was tested in the following hypothesis. There is no significant difference in pre- and post-test scientific thinking scores, as measured by the TOUS test by students completing IPS. The t-ratio between pre- and post-test scores is 2.64. This is high enough that the above null hypothesis can be rejected at the 1 per cent level of confidence on fifty-one degrees of freedom.

Scale I of the TOUS test, "The Scientific Enterprise," is composed of eighteen questions on the following themes: human element in science, communication among scientists, scientific societies, instruments, money, international character of science and interaction of science and society.[4] A significant change in understanding the scientific enterprise can be determined by testing the following hypothesis. There is no significant difference between pre- and post-test scores of "The Scientific Enterprise" portion of the TOUS

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[2] Ibid., p. 10

[3] Ibid.

[4] Ibid., p. 3.

test. The t-ratio for this portion of the tests was .77, which is not statistically significant.

Scale II, "The Scientist," is made up of eighteen questions. They include the following themes: generalizations about scientists as people, institutional pressures on scientists, and abilities needed by scientists.[5] A testable hypothesis for scale II is: there is no significant difference between pre- and post-test scores on "The Scientist" portion of the TOUS test. Here the t-test statistic yielded a ratio of 1.35, which means that the pre-test and post-test scores are not significantly different.

Scale III, "Methods and Aims of Science," is made up of twenty-four questions including themes listed below:

Generalities about scientific methods.
Tactics and strategy or sciencing.
Theories and models.
Aims of science.
Accumulating and falsification.
Controversies in science.
Science and technology.
Unity and interdependence of the sciences.[6]

To determine whether or not a statistical difference existed between the pre- and post-test scores, the following hypothesis was tested. There is no significant difference between pre- and post-test scores on "Methods and Aims of Science" portion of the TOUS test. In this case, the calculated t-ratio was 2.90, which indicates the post-test

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[5] Ibid.

[6] Ibid.

scores will be significantly different from the pre-test scores at the .05 level.

A summary of the preceding statistics including score means and standard deviations can be found in Table 1.

Table 1

Tests of Significance of Change in Scores from Pre-Test to Post-Test on the Total and each Scale of the Test on Understanding Science.

Test		N	Mean	SD	No. of Items	t-ratio	Significant at 5% level
TOUS	pre	52	24.87	7.03	60	2.64	Yes
	post	52	27.37	7.51			
Scale I	pre	52	8.12	2.77	18	.788	No
	post	52	8.46	3.07			
Scale II	pre	52	8.15	3.29	18	1.35	No
	post	52	8.77	2.80			
Scale III	pre	52	8.60	2.73	24	2.90	Yes
	post	52	10.12	3.29			

Another set of hypotheses to be tested involves each scale and the total TOUS test described before for the upper and lower groups. Four hypotheses are presented here for testing with the statistical discussion to follow and in Table 2.

A. There is no significant difference between pre- and post-test scientific thinking scores of the lower or upper group.

B. There is no significant difference between pre- and post-test scores on "The Scientific Enterprise" by the lower or upper group.

C. There is no significant difference between pre- and post-test scores on "The Scientist" by the lower or upper group.

D. There is no significant difference between pre- and post-test scores on "The Methods and Aims of Science" by the lower or upper group.

The analyses of Hypothesis A, TOUS test, yields a t-ratio for the upper group of 2.34. This indicates a significant difference between the pre- and post-test at the 5 per cent confidence level on 16 degrees of freedom. The lower group's t-score was too low to be significant, 1.55.

The t-test of Hypotheses B and C, "Scientific Enterprise" and "The Scientist" did not yeild a high enough ratio for the difference in pre- and post-test for either the high or low group to be considered statistically different from each other: therefore, the null hypotheses must be accepted.

Hypothesis D yielded a t-ratio high enough to be considered significant (2.18 at the 5 per cent confidence level for the upper group. It was 1.94 for the lower group which is not significant at the 5 per cent level.

Table 2, on the next page, contains all the statistics discussed above plus pertinent quantities in table form.

Table 3, page 32, shows the correlation coefficients tetween IQ, ITED Natural Science Reading and Background, Quantitative Thinking and pre- and post- TOUS tests. It also contains t-ratio's for the difference between correlation

Table 2

Test of Significance Between Pre- and Post-Test of the High and Low Groups on the Test on Understanding Science (TOUS

Test		Group	N	Mean	SD	No. of Items	t	Significant at 5% level
TOUS	pre post	high "	17 "	28.24 32.35	7.08 6.72	60	2.34	Yes
	pre post	low "	35 "	23.23 24.94	6.49 6.70	60	1.55	No
Scale I	pre post	high "	17 "	9.71 10.47	2.59 3.12	18	1.03	No
	pre post	low "	35 "	7.34 7.49	2.54 2.56	18	.26	No
Scale II	pre post	high "	17 "	9.18 10.12	3.30 2.42	18	1.38	No
	pre post	low "	35 "	7.69 8.11	3.22 2.76	18	.73	No
Scale III	pre post	high "	17 "	9.41 11.76	3.08 2.47	24	2.18	Yes
	pre post	low "	35 "	8.20 9.31	2.49 3.18	24	1.93	No

coefficients of the pre- and post-TOUS tests and a common variable, IQ, Natural Science Reading, Natural Science Background, and Quantitative Thinking.

The following two hypotheses were rejected:

1. There is no significant change in correlation coefficient between IQ and Scientific Thinking pre- and post-test scores.
2. There is no significant change in correlation coefficient between Background in Natural Science and Scientific Thinking pre- and post-test scores.

The rejection indicates that the correlation coefficient between the pre-test and IQ will be different than the post-test 95 per cent of the time. Rejection of Hypothesis 2 above means that the correlation coefficient between the pre-test and Background in Natural Science will be different that the post-test and Background in Natural Science at the 5 per cent level.

The following two hypotheses must be accepted since the t-ratios are too small to be significant; thus showing that the difference in correlation coefficients are due to chance.

3. There is no significant change in correlation coefficient between Reading of Natural Science and Scienctific Thinking pre- and post-test scores.
4. There is no significant change in correlation coefficient between quantitative thinking and Scientific Thinking pre- and post-test scores.

Table 3

Correlation Coefficients (r) Between Pre- and Post- TOUS Test and Common Variables Along with the t-test Values of Statistical Difference in Correlation Coefficients

Common Variables	Pre-test	Post-test	t-ratio for difference in r's	Difference in r's sig. at 5% level
IQ	r=.334	r=.644	3.428	Yes
Natural Science Background	r=.471	r=.673	2.282	Yes
Natural Science Reading	r=.608	r=.667	.696	No
Quantitative Thinking	r=.321	r=.468	.829	No

All the correlation coefficients are significant at .05 level.

Another interesting statistic is the partial correlation coefficient found between two variables with the effect of the third eliminated. Tate also points out two important assumptions underlying the technique through:

> (1) linearity of regression of the two variables upon the third variable, and (2) equal scattering of the values of the two variables for different values of the third variable. The second assumption is analogous to the homoscedasticity in the two-variable problem.[7]

This can be used to determine theoretically what the correlation coefficient between the pre- and post-test would be if the Intelligence, Natural Science Background, Natural Science Reading, or Quantitative Thinking ability

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[7] Merle W. Tate, Statistics in Education and Psychology (New York: Macmillan Company), 1965, p. 170.

was controlled. It can be seen on Table 4, that controlling the IQ's gave the greatest correlation between pre- and post-test (r=.601). Very close to the controlled IQ was the controlled quantitative thinking ability (r=.572). Controlling the effects of Natural Science Background and Reading abilities gave more erratic pre- and post-test correlations, .512 and .414 respectfully.

Table 4

Partial Correlation Coefficients Between Pre- and Post TOUS Test with the Effects of IQ, Natural Science Background, Natural Science Reading, and Quantitative Thinking Eliminated

Control	Pre-test	Post-test	Partial Correlation with the effects of the control eliminated
IQ	r_{12}=.334	r_{13}=.644	$r_{23.1}$=.601
Natural Science Reading	r_{12}=.608	r_{13}=.667	$r_{23.1}$=.414
Natural Science Background	r_{12}=.471	r_{13}=.673	$r_{23.1}$=.512
Quantitative Thinking	r_{12}=.321	r_{13}=.468	$r_{23.1}$=.578

All correlations are significant at the .05 level.

Part II

The second general part of the analysis is concerned with an item analysis of the Test on Understanding Science (TOUS) to determine the specific behaviors changed between testing periods. Here a comparison is made between the pre-test and post-test responses to determine if they changed significantly toward or away from the correct answer. By using McNemar's chi square test of change, the investigator was able to separate the items which changed significantly.

Procedure for completing the analysis included (1) finding proportions of groups, lower, upper, or entire, marking each response on each of the sixty test items on the pre-test and the post-test and (2) the necessary break-down to complete McNemar's chi squared test. This statistic requires finding the frequency of right and wrong responses on the pre- and post-test and arranging the combination in a four-cell contingency table like the following example.[8]

		Pre-test	
		Incorrect	Correct
Post-test	Correct	A	B
	Incorrect	C	D

The letter A represents the number of students who responded correctly on the post-test and incorrectly on the pre-test; B represents the correct answer on both tests; C represents incorrect responses on both tests; D means that there was a correct response on the pre-test and an incorrect one on the post-test. The formula to calculate chi squared values is as follows on the next page:

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[8]Quinn McNemar, Psychological Statistics, (New York: John Wiley and Sons, 1962) p. 225.

$$X^2 = \frac{(A-D)^2}{A+D}$$, with one degree of freedom.[9]

A complete listing of chi square values for each of the 60 test items is in the appendix, Table 1. A discussion of each of the particular test items and the correct response with a significant change at the 5 per cent follows.

Test item 4 was the first question to have a chi squared value greater than 3.84, minimum for 5 per cent confidence limits. It reads as follows:

The people and government of a country influence scientific activity:

A. very little, because scientists are quite isolated from the rest of society.
B. a little, because people must be willing to become scientists and to pay for science.
C. a great deal, because most scientists work for the government and must follow its instructions.
<u>D</u>. a great deal, because the education and support given to scientists depend on how the people feel about science.

Both the low and entire group made significant gains toward the correct response, D. The upper group did not make a statistical gain, but .71 marked item 4 correctly on the pre-test. A statistically significant improvement would be difficult to obtain. An extended breakdown of the fraction of students making each response is contained in Table 5, on page 44.

Test item 5 showed a marked increase in response B, which is the correct answer. The question reads as follows:

In the 17th century, Newton formulated his laws of motion and the theory of universal gravitation, which were eventually accepted by all physicists. In the 20th century, Einstein proposed a much broader theory of relativity, which physicists have generally accepted. Physicists today consider

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[9] Ibid.

Newton's ideas as:

A. mistaken notions, because of Newton's limited experience.
B. part of Einstein's theory, as a special case.
C. applicable only to physical events in another world.
D. superior to Einstein's, because they have a longer tradition.

The content of the question was not discussed in physical science class. Apparently the desired method of thinking developed during physical science, and that is what carried over to the test question.

Table 5, on page 44 indicated that the upper and entire groups made significant gains toward the correct answer on item 5. The low group gained to a certain degree, but not statistically significant. It is interesting to note that the low group responded to D less frequently, and the upper group marked A less often.

Page 45, Table 5, contains test item 12 along with the proportion of students selecting each response and the chi square test of change between the pre- and post-test. The question was stated as follows:

The principal aim of science is to:

A. verify what has already been discovered about the physical world.
B. explain natural phenomena in terms of principals and theories.
C. discover, collect and classify facts about animate and inaminate nature.
D. provide the people of the world with the means for leading better lives.

Response B was marked by 54 per cent of the low group and by only 35 per cent of the upper group on the post-test. The 35 per cent was equal to the frequency of response of answer C.

The concept, the principle aim of science, was perceived more accurately by the lower group. Even though the upper group did not change its response to the correct answer sufficiently to yeild a chi squared value high enough to be significant, the upper group decreased the frequency with which C was marked from 71 to 35 per cent. These high frequencies could evolve from the success the upper group had experienced in pervious non inquiry science courses oriented toward discovering, collecting and classifying facts.

Test item 14, Table 5, located on page 46 follows:

In 1935 a Japanese physicist, Hideki Yu Kawa, made an important contribution to the theory of nuclear physics. This occurence was not considered unusual because:

A. nuclear physics is taught in schools throughout the world.
B. almost anyone can contribute a scientific theory.
C. most Asian scientists know a great deal about nuclear physics.
<u>D</u>. people from many countries contribute to science.

Response D was answered correctly by 50 per cent of the entire group of students on the pre-test. Students in all groups improved their answer selection on the post-test sufficiently so that similar results can be expected 95 per cent of the time.

In test item 19, there was a statistically significant change away from the correct answer in the following question.

If a physicist and a livestock dealer were to walk into an experimental biology laboratory together for the first time, which man would probably understand what was going on there more quickly?

A. both men would understand at about the same time, because neither of them is a research biologist.
B. the livestock dealer, because the training for his job most likely included the methods of experimental biology.
<u>C</u>. the physicist, because biologists and physicists have similar points of view toward investigating natural phenomena.

D. the physicist, becuase physicists do the same kind of laboratory work that biologists do.

All three groups decreased in frequency of correct responses, but the entire group was the only one to change greatly. Over 50 per cent of the students answered item 19 correctly on the pre-test and over one-third answered it correctly on the post-test. The correct response was chosen more frequently than any other choice. Responses B and D were the incorrect answers which were indicated more frequently on the post-test than pre-test. A complete breakdown of percentages of students marking each response can be seen in Table 5, page 47.

Item 33 had special directions which were:

In the following item, there is a statement about a scientist on the left and a reason for that statement on the right.
A. if both the statement and the reason are generally true;
B. if the statement is generally true but the reason is false;
C. if the statement is false but the reason is generally true;
D. if both the statement and the reason are false.

The statement of item 33 is:

Work in the various branches of science requires the same abilities and skills	BECAUSE	scientific methods are used in all branches of science.

In item 33 the low group improved their score significantly, from 20 per cent on the pre-test to 46 per cent on the post-test. However, the upper group did not improve greatly. Over all however, the entire group did improve statistically. Other percentages of students making each response can be found in Table 5, page 48.

Test item 41 appears in Table 5, on page 49 along with the individual statistics. The question is stated on the following page.

Which one of the following statements best describes the connection between science and technology today?

<u>A</u>. technology involves the practical application of scientific knowledge.
B. science depends on technology for ideas and the organization of experimental work.
C. workers in science use the laws and principles discovered by workers in technology.
D. technology is the part of science that deals with mechanical problems.

The correct response, A, was marked more often by all groups on the post-test rather than the pre-test. There was not a great enough change in response to be significant, but it was consistent for it to be so when the entire group was analyzed. Incorrect choice B decreased in frequency of selection more than any other answer.

Test item 52 was the second question to have a statistical change away from the correct answer. The question appeared on the pre- and post-test as follows:

If we were to check on the contributions to science that have been made in various countries since 1900, we would expect to find representation chiefly from:

A. the United States and Russia.
B. England and France.
C. the four countries listed in A and B.
<u>D</u>. the countries listed and others.

Response D, the correct answer, was marked less frequently on the post-test than on the pre-test by all groups. Each of the incorrect choices increased in frequency of response to a lesser degree by the entire group. A and C both were more popular answers than the correct one, D. Proportion of students making each response can be seen in Table 5, on page 50.

Items 56 and 60 show a statistical significant change for the upper group only. They were unique in that characteristic.

Item 56 was stated in the following way:

If a geologist is attempting to establish a theory about the origin of mountains, he would:

A. rule out all previous attempts to explain mountain-building.
B. correlate all his evidence with geologic maps.
C. see if it explains the known data on mountain-building.
D. study the geological record of all mountains in the United States.

The change by the upper group yielded a significant chi square value of 50 per cent. The low group's response showed little change which caused the entire group to have a chi square value of less than 3.84. A complete breakdown of responses along with the question can be found in Table 5 on page 51.

Question 60 was the last item to have any statistical change. It was also the last question on the scientific thinking inventory. Item 60 was worded in the following manner:

In discussing our country's disarmament policy, a famous scientist declared that we must continue our experimenting with nuclear bombs. What is the best evaluation we can give to this scientist's statement?

A. His conclusion is probably right, since he approaches the problem with a scientific attitude.
B. His conclusion is probably wrong, because scientists seem to be trying to destroy the world.
C. His conclusion and reasons are probably correct, because scientific results are the most reliable kind.
D. His conclusion and reasons should be weighed according to his knowledge of international affairs.

The correct answer was response D. This was selected by nearly 50 per cent of the students on the pre-test. Then on the post-test, only 54 per cent chose response D. The significant change came when the upper group increased its percentage of correct answers from 53 to 82. A slight decrease in the percentage of correct responses among the low group caused little change in the entire group. All of the proportions of students marking each response on item 60 can be seen in Table 5, page 52.

The findings in this research project are only the changes which have occurred to the students involved. There was no control group with which to compare the experimental research group; therefore, the study consists of a comparison between two pre- and post-TOUS tests. This comparison yeilded several significant changes which can be summarized in the following way.

Summary

The first seven changes listed are those involving the entire group, all physical science students.

1. IPS improved the students' scientific thinking ability.
2. IPS improved the students' understanding of the "Methods and Aims of Science", but did not improve their understanding of the other two scales of the TOUS test, "The Scientific Enterprise" or "The Scientist".
3. The TOUS post-test correlated better with IQ and Natural Science Background than did the pre-test.
4. Theoretically controlling or partialing out, IQ and

Quantitative Thinking, Natural Science Background, and Natural Science Reading, respectively, yielded lesser correlations between the pre- and post-test.

5. Six test items had a definite change toward the correct answer. They were item numbers 4, 5, 12, 14, 33, and 41.
6. Two test items had a definite change away from the correct answer. They were items 19 and 52.
7. Five of the eight test questions with a significant change in response were in Scale III, "Aims and Methods of Science" of the TOUS.

Dividing the entire group into two subgroups, lower and upper, produced changes that were significant for one group or the other. These particular changes include the following listed below:

8. The upper group improved their scientific thinking ability whereas the low group did not.
9. Scale III, "The Aims and Methods of Science," had a significant improvement on the test scores for the high group only.
10. The low group changed their response significantly toward the correct answer on test items 4, 13, and 33.
11. The upper group changed their response significantly toward the correct answer on test items 5, 56, and 60.

Table 5

Proportion of Students Selecting Each Response and Chi Square Test for a Sample of TOUS Items on Which There Was Significant Pre- to Post-Test Change

Item 4

The people and government of a country influence scientific activity:

A. very little, because scientists are quite isolated from the rest of society.
B. a little, because people must be willing to become scientists and to pay for science.
C. a great deal, because most scientists work for the government and must follow its instructions.
D. a great deal, because the education and support given to scientists depend on how the people feel about science.

Group	N	Proportion of Students Selecting Each Response A	B	C	D	Chi Square Test of Pre- to Post-Test Change
Low pre	35	.11	.11	.37	.40	
post	35	.06	.03	.26	.66	
Upper pre	17	.12	0	.18	.71	Low $X^2 = 5.40$*
post	17	0	.06	.18	.76	Upper $X^2 = .20$
Entire pre	52	.12	.08	.31	.50	
post	52	.04	.04	.23	.69	Entire $X^2 = 5.00$*

_ Indicates correct answer.

* Significant at .05 level.

Table 5 (continued)

Item 5

In the 17th century, Newton formulated his laws of motion and the theory of universal gravitation, which were eventually accepted by all physicists. In the 20th centruy, Einstein proposed a much broader theory of relativity, which physicists have generally accepted. Physicists today consider Newton's ideas as:

A. mistaken notions, because of Newton's limited experience.
<u>B</u>. part of Einstein's theory, as a special case.
C. applicable only to physical events in another world.
D. superior to Einstein's, because they have a longer tradition.

Group		N	Proportion of Students Selecting Each Response A	B	C	D	Chi Square Test of Pre- to Post-Test Change
Low	pre	35	.09	.54	.20	.17	Low $X^2 = 1.47$
	post	35	.11	.69	.18	.06	
Upper	pre	17	.35	.41	.18	.06	Upper $X^2 = 8.00$**
	post	17	.06	.88	.06	0	
Entire	pre	52	.17	.50	.19	.19	Entire $X^2 = 6.76$**
	post	52	.10	.75	.12	.04	

** Significant at .01 level.

_ Indicates correct answer.

Table 5 (continued)

Item 12

The principal aim of science is to:

A. verify what has been already discovered about the physical world.
B. explain natural phenomena in terms of principals aand theories.
C. discover, collect and classify facts about animate and inanimate nature.
D. provide the people of the world with the means for leading betterrlives.

Group		N	Proportion of Students Selecting Each Response				Chi Square Test of Pre- to Post-Test Change	
			A	B	C	D		
Low	pre	35	.20	.15	.31	.35		
	post	35	.11	.54	.20	.15		
Upper	pre	17	0	.24	.71	.06	Low	$X^2 = 10.89$**
	post	17	.06	.35	.35	.24	Upper	$X^2 = 1.80$
Entire	pre	52	.13	.17	.44	.25		
	post	52	.10	.48	.25	.17	Entire	$X^2 = 12.56$**

** Significant at .01 level.

_ Indicates correct answer.

Table 5 (continued)

Item 14

In 1935 a Japanese physicist, Hideki Yu Kawa, made an important contribution to the theory of nuclear physics. This occurrence was not considered unusual because:

A. nuclear physics is taught in schools throughout the world.
B. almost anyone can contribute a scientific theory.
C. most Asian scientists know a great deal about nuclear physics.
<u>D</u>. people from many countries contribute to science.

Group		N	A	B	C	D	Chi Square Test of Pre- to Post-test Change	
			Proportion of Students Selecting Each Response					
Low	pre	35	.09	.31	.15	.43		
	post	35	.15	.15	.06	.66		
Upper	pre	17	.12	.06	.18	.65	Low	$X^2 = 3.56$
	post	17	.06	0	.12	.82		
							Upper	$X^2 = 1.80$
Entire	pre	52	.10	.23	.15	.50		
	post	52	.12	.10	.08	.71	Entire	$X^2 = 5.26$*

*Significant at .05 level.

_ Indicates correct answer.

Table 5 (continued)

Item 19

If a physicist and a livestock dealer were to walk into an experimental biologyylaboratory together for the first time, which man would probably understand what wasgoing on there more quickly?

A. both men would understand at about the same time, because neither of them is a research biologist.
B. the livestock dealer, because the training for his job most likely included the methods of experimental biology.
<u>C</u>. the physicist, because biologists and physicists have similar points of view toward investigating natural phenomena.
D. the physicist, because physicists do the same kind of laboratory work that biologists do.

Group		N	Proportion of Students Selecting Each Response				Chi Square Test of Pre- to Post-test Change
Low	pre	35	.17	.11	.60	.09	
	post	35	.09	.26	.46	.20	
Upper	pre	17	.18	.18	.47	.18	Low X^2= -2.27
	post	17	.29	.29	.18	.24	Upper X^2= -2.78
Entire	pre	52	.17	.13	.56	.12	
	post	52	.15	.27	.37	.21	Entire X^2= -5.00*

--Change from right to wrong answer.

* Significant at .05 level.

_ Indicates correct answer.

Table 5 (continued)

Item 33

SPECIAL DIRECTIONS FOR ITEM 33

In the following item, there is a statement about a scientist on the left and a reason for that statement on the right.
A. if both the statement and the reason are generally true;
B. if the statement is generally true but the reason is false;
C. if the statement is false but the reason is generally true;
D. if both the statement and the reason are false.

STATEMENT

Work in the various branches of science requires the same abilities and skills	BECAUSE	scientific methods are used in all branches of science.

Group		N	Proportion of Students Selecting Each Response A	B	C	D	Chi Square Test of Pre- to Post-Test Change
Low	pre	35	.51	.17	.200	.11	
	post	35	.40	.06	.46	.09	
Upper	pre	17	.41	.12	.41	.06	Low $X^2 = 9.00$**
	post	17	.29	.06	.46	.12	Upper $X^2 = 1.00$
Entire	pre	52	.48	.15	.27	.10	
	post	52	.37	.06	.48	.10	Entire $X^2 = 8.00$**

** Significant at .01 level.

_ Indicates correct answer.

Table 5 (continued)

Item 41

Which one of the following statements best describes the connection between science and technology today?

<u>A</u>. technology involves the practical application of scientific knowledge.
B. science depends on technology for ideas and the organization of experimental work.
C. Workers in science use the laws and principles discovered by workers in technology.
D. technology is the part of science that deals with mechanical problems.

Group		N	Proportion of Students Selecting Each Response A	B	C	D	Chi Square Test of Pre- to Post-Test Change	
Low	pre	35	.23	.43	.09	.26		
	post	35	.37	.31	0	.31		
Upper	pre	17	.35	.29	.09	.24	Low	$X^2 = 2.57$
	post	17	.59	.06	.02	.24		
							Upper	$X^2 = 2.66$
Entire	pre	52	.27	.38	.10	.25		
	post	52	.45	.23	.01	.30	Entire	$X^2 = 5.00$*

* Significant at .05 level.

_ Indicates correct answer.

Table 5 (continued)

Item 52

If we were to check on the contributions to science that have been made in various countries since 1900, we would expect to find representation chiefly from:

A. the United States and Russia.
B. England and France.
C. the four countries listed in A and B.
<u>D</u>. the countries listed and others.

Group		N	Proportion of Students Selecting Each Response				Chi Square Test of Pre- to Post-Test Change	
			A	B	C	D		
Low	pre	35	.26	.09	.31	.31		
	post	35	.29	.17	.35	.15	Low	$X^2 = -3.27$
Upper	pre	17	.25	0	.25	.47		
	post	17	.41	.06	.24	.29	Upper	$X^2 = -3.00$
Entire	pre	52	.25	.06	.29	.37	Entire	$X^2 = -5.55$*
	post	52	.33	.13	.31	.19		

* Significant at .05 level.

_ Indicates correct answer.

\- Change from right to wrong answer.

Table 5 (continued)

Item 56

If a geologist is attempting to establish a theory about the origin of mountains, he would:

A. rule out all previous attempts to explain mountain-building.
B. correlate all his evidence with geologic maps.
C. see if it explains the known data on mountain-building.
D. study the geological record of all mountains in the United States.

Group		N	Proportion of Students Selecting Each Response A	B	C	D	Chi Square Test of Pre- to Post-Test Change	
Low	pre	35	.09	.29	.15	.40		
	post	35	.17	.23	.20	.35		
Upper	pre	17	.29	.24	.12	.29	Low	$X^2 = .40$
	post	17	.12	.12	.41	.35	Upper	$X^2 = 5.00$*
Entire	pre	52	.15	.27	.13	.37		
	post	52	.15	.19	.27	.35	Entire	$X^2 = 3.27$

* Significant at .05 level.

_ Indicates correct answer.

Table 5 (continued)

Item 60

In discussing our country's disarmament policy, a famous scientist declared that we must continue our experimenting with nuclear bombs. What is the best evaluation we can give to this scientist's statement?

A. His conclusion is probably right, since he approaches the problem with a scientific attitude.
B. His conclusion is probably wrong, because scientists seem to be trying to destroy the world.
C. His conlusion and reasons are probably correct, because scientific results are the most reliable kind.
_D._ His conclusion and reasons should be weighed according to his knowledge of international affairs.

Group		N	Proportion of Students Selecting Each Response A	B	C	D	Chi Square Test of Pre- to Post-Test Change	
Low	pre	35	.11	.11	.23	.43		
	post	35	.15	.17	.20	.40		
Upper	pre	17	.18	.06	.19	.53	Low	X^2 -.07
	post	17	.12	0	.06	.82		
							Upper	X^2 5.00*
Entire	pre	52	.13	.10	.21	.48		
	post	52	.13	.12	.15	.54	Entire	X^2 .89

* Significant at .05 level.

\- Change from right to wrong answer.

_ Indicates correct answer.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

If "Introductory Physical Science" is used in the high school as a physical science course and instructed according to its author's suggestions, several changes can be expected to occur. These changes include:

1. Improvement of students' scientific thinking ability.
2. Improvement of students' aims and methods of science.
3. An increased correlation between IQ and scientific thinking.
4. An increased correlation between natural science background and scientific thinking.
5. Students' thinking ability will be shaped in such a way that more students will indicate the correct response to test items 4, 5, 12, 14, 33, and 41.
6. Students' thinking ability will be shaped in such a way that less students will indicate the correct response to test items 19 and 22.

Reading and background of natural science abilities affects outcomes of changes to such an extent that these two qualities must be taken into account when considering the merits of IPS as a high school physical science course. Some particular changes which will be different for the upper and lower groups are listed on the next page.

1. Unless the unique needs of the lower group are emphasized, only the upper group will increase their scientific thinking ability.
2. Unless the unique needs of the lower group are emphasized, only the upper group will gain in knowledge of methods and aims of science.
3. The lower group will improve their responses to test items 4, 12, and 33.
4. The upper group will improve their responses to test items 19 and 52.

It would be recommended that a future user of IPS in th the high school observe closely the changes experienced by students as shown in this research study. He then could then adjust his instructional techniques and methods to amplify other desirable behaviors and counteract the negative changes (away from the correct answers) which occurred in this study. The department using IPS should also bear in mind that some changes will occur to the entire group, but different changes can be expected from the upper group than the lower group.

It is further recommended that a study be made of actual scientific principles conveyed to students by IPS. Then, a user of IPS in the high school would have research analysis of two primary objectives of a physical science course, to convey scientific principles and to improve scientific thinking ability.

APPENDIX

Table 1

Chi-Squared Values of TOUS Test Items by Physical Science Students in Denison High School, 1970-71

Test Item	X^2 Lower Group	X^2 Upper Group	X^2 Entire Group
1.	1.33	-.33	.60
2.	1.92	1.00	2.88
3.	.11	2.00	.69
4.	5.40*	.20	5.00*
5.	1.47	8.00**	6.76**
6.	.11	.33	.60
7.	1.47	-1.28	.17
8.	- .33	- .33	-.60
9.	1.23	1.00	2.13
10.	- .06	0.00	- .05
11.	- .08	- .67	- .47
12.	10.89**	1.80	12.56
13.	.25	.67	.73
14.	3.56	1.80	5.26*
15.	5.00*	2.00	7.00**
16.	.29	.14	.43
17.	- .09	0.00	- .08
18.	0.00	1.80	.60
19.	-2.27	-2.78	-5.00*
20.	0.00	3.57	.81
21.	- .50	0.00	- .29
22.	-2.25	.67	- .70
23.	- .08	0.00	- .06
24.	- .11	-3.00	-1.33
25.	0.00	.14	.07
26.	0.00	-1.28	- .33
27.	-1.14	- .20	-1.31
28.	- .81	- .50	-1.32
29.	-2.27	0.00	-1.19
30.	1.70	2.00	3.52
31.	-1.00	.40	.15
32.	.17	1.80	1.47
33.	9.00**	1.00	8.00**
34.	-1.47	-1.00	-2.33
35.	1.92	-2.27	0.00
36.	.60	- .20	.20
37.	- .60	- .11	- .67
38.	.08	1.29	1.80
39.	- .60	0.00	- .47
40.	.06	.33	.20

Table 1 (continued)

Test Item	X^2 Lower Group	X^2 Upper Group	X^2 Entire Group
41.	2.57	2.66	5.00*
42.	-1.00	1.00	1.80
43.	-1.00	- .67	-1.60
44.	- .07	- .67	- .42
45.	0.00	2.78	.93
46.	.07	2.66	1.32
47.	2.78	- .20	2.57
48.	1.63	- .67	.57
49.	.09	.50	.47
50.	1.47	.20	1.64
51.	2.25	- .14	1.08
52.	-3.27	-3.00	-5.55*
53.	- .07	1.80	.20
54.	.53	2.27	2.29
55.	.05	.20	.29
56.	.40	5.00*	3.27
57.	- .07	2.00	.43
58.	.22	2.67	1.50
59.	-4.00	1.00	-1.00
60.	- .07	5.00*	.89

* Significant at .05 level.

** Significant at .01 level.

\- Change from right to wrong answer.

Table 2

Raw Scores of Low Group

Student	Pre TOUS Test Scales I	II	III	Total	Post TOUS Test Scales I	II	III	Total	IQ	Nat. Sci. Back-ground	Nat. Sci. Reading	Quan. Think-ing
10 5 4	6	3	5	14	8	8	7	23	109	17	9	18
10 5 8	4	3	7	14	2	5	5	12	74	5	11	10
10 5 11	7	6	6	19	8	7	12	27	99	18	12	5
10 1 13	9	4	7	20	10	10	7	27	88	11	9	1
10 6 20	6	6	7	19	7	2	1	10	74	4	10	5
10 6 25	6	7	6	19	6	6	5	16	95	12	13	9
10 1 22	3	4	5	12	4	3	7	14	89	8	5	5
10 5 31	6	5	6	17	7	6	6	19	97	9	8	10
11 6 1	7	12	2	21	7	7	9	23	84	1	10	14
11 5 5	8	8	8	24	7	11	12	30	105	19	14	15
11 1 10	10	8	12	17	11	9	12	30	100	19	17	12
11 5 14	8	14	11	33	8	11	13	32	101	14	11	12
11 5 16	11	9	10	30	8	4	10	22	103	21	10	10
11 6 13	5	5	9	17	9	10	11	31	110	20	11	18
11 6 16	7	5	9	21	4	9	11	24	108	13	7	12
11 6 17	6	3	9	18	7	5	8	20	106	3	8	11
11 6 19	7	10	8	25	6	9	10	25	101	14	16	12
11 1 16	9	9	10	28	11	10	16	37	112	18	18	16
11 6 23	10	10	14	34	13	12	12	37	104	17	20	12
11 6 26	10	6	12	28	2	7	11	20	86	18	18	19
12 5 1	9	4	5	18	8	11	10	29	108	13	13	10
12 6 5	3	3	9	15	7	11	4	22	106	12	2	11
12 5 7	13	12	10	35	10	11	10	31	104	12	14	11
12 1 4	2	6	9	17	10	16	5	21	116	21	15	20
12 6 7	8	8	9	25	5	6	9	20	104	20	13	18

Table 2 (continued)

Student	Pre TOUS Test Scales I	II	III	Total	Post TOUS Test Scales I	II	III	Total	IQ	Nat. Sci. Back-ground	Nat. Sci. Reading	Quan. Think-ing
12 1 5	9	13	11	33	9	7	6	22	100	15	15	19
12 6 8	7	12	6	25	6	9	12	27	104	19	19	22
12 5 13	12	12	8	32	6	11	9	26	96	14	13	14
12 5 20	5	10	8	23	6	7	9	22	99	16	15	19
12 1 14	8	9	9	26	12	11	12	35	105	19	15	14
12 5 22	7	9	10	26	9	6	15	30	103	19	21	23
12 5 28	7	11	10	28	7	11	9	27	113	20	18	27
12 6 27	10	6	11	27	6	6	9	21	103	18	14	16
12 6 29	8	7	8	20	7	11	12	30	103	20	14	16
12 5 32	11	11	11	33	9	8	11	28	94	20	15	11

Table 3

Raw Scores of High Group

Student	Pre TOUS Test Scales I	II	III	Total	Post TOUS Test Scales I	II	III	Total	IQ	Nat. Sci. Back-ground	Nat. Sci. Reading	Quan. Think-ing
10 5 17	6	5	6	17	7	8	9	24	109	17	9	11
11 5 2	8	14	8	30	10	14	10	34	103	18	20	12
11 1 8	10	8	12	30	11	9	12	32	128	23	20	25
11 6 10	12	10	11	33	12	13	12	37	109	25	20	20
11 1 11	12	9	14	33	10	10	8	28	104	21	17	11
11 6 22	12	7	8	27	9	8	13	30	113	20	19	12
11 1 19	9	9	8	26	12	8	17	37	99	21	20	16
11 5 29	8	10	9	27	9	7	11	27	117	21	17	21
11 6 28	8	8	12	18	5	9	9	23	104	24	25	20
11 6 30	8	8	12	28	8	13	11	32	112	23	14	16
12 1 1	10	12	14	34	15	13	4	42	115	28	24	21
11 1 2	8	8	11	27	15	11	11	37	107	21	22	16
12 1 7	15	11	9	35	16	12	14	42	125	27	28	29
12 6 14	11	6	7	24	12	8	9	29	96	21	23	11
12 5 19	10	13	10	33	12	12	11	35	108	23	26	18
12 5 25	5	2	7	14	9	9	12	30	115	22	17	20
12 5 26	13	15	12	40	12	13	19	44	123	27	28	26

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